COMPRESSED AIR MAGAZINE

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COMPRESSED AIR ENGINEERING

By Frank Richards.

The employment of compressed air as the agency of power transmission on some of the Barge Canal contracts, as has been described elsewhere (see page 5323), suggests inquiry as to the advantages and the disadvantages of such transmission. Of course, in a way, contractors use their own experience and judgment, and select and determine their own means and methods, the only ultimate consideration being as to the perfect execution of the work and the complete satisfying of the specifications; but, still, if the means adopted find general approval from the start the satisfying progress and the winning finish may be more confidently predicted.

The great engineering works of the ancients, and even those of the moderns up to a century ago, were executed, so far as we know, almost entirely by human hands using the primitive tools. To-day if the pick, the shovel and the wheelbarrow, backed by the main strength of the laborer, are ever permitted upon works of any extent, the fact calls at once for explanation or apology.

With the advent of machinery, as modernly employed, steam was almost universally adopted as the source of power and, subject to the limitations of partially developed mechanical practice, the steam was applied as directly as possible to the machines to be operated or to the work to be done. For all outdoor engineering work the pumps, the hoists, the pile drivers, the excavators, the rock breakers, the means of haulage and what not, were all directly, and usually individually, steam driven, and apparently no one asked for, or indeed thought of, any radical change or improvement in motive power for such work or in the system of its distribution.

It has always been practically impossible, however, to use steam in mining, in tunnel driving or in subaqueous work of any kind, and practice in these lines developed and improved slowly in consequence. The rock drill it was which first demanded the air compressor, and the earlier builders of air compressors in large, commercial units found all their business provided for them by the rock drills, and quite naturally to-day the largest builders of air compressors are also the principal rock drill makers.

This initial and compulsory employment of compressed air for rock drills in mines and tunnels and similar work developed rapidly, compressors became numerous and practical men began to appreciate the ready applicability of air to the various uses hitherto monopolized by steam. It happens that practically all the apparatus which is operated by air is similar to, if not identical with, that which is steam driven, and all steam driven machines can be driven, and generally better driven, by compressed air. Where a supply of compressed air has necessarily been provided for the strictly underground machines, and where there have been outdoor machines as part of the same general plant, it has often been a simple matter to pipe the air to the latter also, and thus to have the one power

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system cover the entire series of associated mechanisms. Wherever this has been done compressed air has shown itself not only permissible but extremely desirable and profitable, even for the additional items of employment not strictly compulsory.

As to the better drive of air than steam for the same machinery, that is easily demonstrable. Rock drills whether to be operated by air or steam are practically identical in design and construction, the only difference being usually in the style of stuffing box used. All drills are run for a considerable time at the factory to get them broken in and running smoothly and satisfactorily before they are sent out. All the steam drills are first worked with air, and after they work all right with that then steam is used, and it invariably requires a long and tedious coaxing before the drills can be made to run as freely and as lively with steam as they did with air. The first admission of the steam causes unequal heating and expansion of the closely fitted members, and also the condensed steam chokes the small and tortuous passages about the valves; also the lubricant which is used, when once it wets the surfaces of the air operated tool, remains a long time, while when steam is used in a drill for only a few minutes, so that it is thoroughly heated, if the drill is taken apart and the surfaces supposed to have been lubricated examined no trace of oil will be found on them, and they will usually be "as dry as a bone." The favorable experience with the rock drill, as to the use of air in preference to steam as the operating fluid, is repeated with all other styles of normally steam driven machines. The air-operated machine is always and instantly ready, and only the throttle requires to be manipulated or thought of.

In driving the tunnels of the Pennsylvania Railroad under the Hudson river at New York, it is not conceivable how the work could have been done without the constant aid of compressed air; but for the enormous excavation required for the passenger station of the same company, which was all outdoor work, the use of compressed air was not imperative, still air was adopted for this work also entirely upon its merits by men who knew, and the results have fully proved the wisdom of the choice.

The similar and even more extensive work of excavation for the new station of the New York Central in the heart of New York City, this also entirely outdoor work, is similarly being done entirely with compressed air, as the power transmitter.

For engineering works of large extent and the completion of which will require months or years, so as to make the installation of a suitable plant worth while, compressed air is becoming more and more the favorite where formerly only steam would have been thought of. Some of the largest stone quarries which have promise of permanance of output are now operated entirely from central air compressing plants. The compressed air installations at Crescent, at Lock 7, and on the contracts in the western sections of the Barge Canal are fully warranted by successful engineering experiences.

As has happened before in engineering matters, and in other things having to do with the world's progress, it has not been the scientific investigators, the official testers of efficiencies, those whose function it is to explain the why of things, who have been the leaders and promoters in this extension of general out-door compressed air practice. For appreciation and opportunity compressed air is indebted almost entirely to the practical men who have been most closely in touch with it, and now the theorists can pat them on the back and patronizingly assure them that "they builded better than they knew." Perhaps so.

It is by no means difficult, after the practical man has established the practice, to find many cogent reasons which justify the extensive and permanent employment of compressed air. The quite general impression has been that, while compressed air has many things to recommend it in practice, it is still very wasteful of power, or that the amount of power ultimately realized at the extremities of the piping systems where the air is used, is but a small fraction of that which is consumed in the initial compression of the air. The power losses in the use of compressed air have been harped upon until some persons have been able to think of nothing else in connection with it.

The truth is really in the other direction, when the use of air is compared with that of steam for the lines of work we are here considering. It is quite possible to show that

the use of air compressed by steam at a central station, instead of using steam direct in the individual widely distributed machines, effects a distinct saving at the coal pile and an enormous saving of operative labor in addition, besides securing the many accompanying minor advantages not generally enumerated, and often not even thought of.

Of course, it is an easy thing to cite cases showing how power is wasted by the employment of compressed air for power transmission. Some such occurred early in the compressed air experience of the writer hereof. For nearly my first lesson there was a straight line, single stage air compressor running at normal speed and the entire air output of it was used to drive a steam pump down in a coal mine, the length of piping being not more than 1,000 feet; and the greatest efficieny I was able to figure out in the case, starting with the indicator card of the steam cylinder of the compressor, was 19 per cent. Of course, some of the loss here shown was chargeable to the pump itself, with its large clearance spaces to fill, and the use of the air entirely without expansion. Many cases where the too familiar steam pump is driven by compressed air would show results worse than this, while other types of apparatus so operated might show up somewhat better.

In another case I had a straight line, single stage compressor, with piping not exceeding 300 ft. to a small fly-wheel-governor, slide-valve steam engine of suitable size. It was possible to adjust the work of the engine—the work was the driving of a fan—and the speed of the compressor so that the one would just supply the other and each could be brought to a constant running speed. In this case the air passed through a heater by which its temperature was raised 150 degrees Fahr. and its volume correspondingly increased before it entered the engine. The best efficiency I could figure out in this case was 37 per cent.

All who have to do with compressed air can cite instances of power losses such as this, and they would seem to be conclusive against the use of the air, so far as power economy is concerned, were it not for the fact that a decidedly worse case can be made out against the use of steam. In the case where numerous machines are distributed over considerable areas, where the machines are all of them operated intermittently and with constantly varying loads, it is obviously impossible to make tests of power consumption for record or comparison. It is possible, however, to come to some agreement as to probable performance. A hoisting engine may be assumed to be as good an example as any of the machines to be driven. It will probably be fair to assume that the hoisting engine driven by air and working under fair ordinary conditions will, when actually working, realize 25 per cent. of the power consumed in compressing the air. That is, if a horse-power at the compressor costs 4 pounds of coal per horse-power hour the coal cost at the hoisting engine will be 16 pounds per horse-power hour.

One important thing in connection with each employment of compressed air is that it costs practically nothing except for the work actually done by it, and only while the work it being done. There are no heat losses after the air is once cooled and the losses by leakage, which we speak of later, are practically negligible. To cover all imaginable losses, however, we may concede an additional 5 per cent., thus allowing the net horse-power realized in work actually done by the compressed air driven machine to be only 20 per cent. of the initial horse-power at the steam driven compressor, and making the coal cost per horse-power hour, therefore, five times as great as at the compressor, or 20 pounds per horse-power hour.

As a matter of record it is quite possible to operate central compressor plants with compound steam cylinders and condensers and with boilers and boiler accessories designed and operated for economy, with less than 3 pounds of coal per horse-power hour. Then five times this as above would be only 15 pounds as the coal cost at the air driven machine.

When water can be utilized as the source of power with or without the employment of electricity for transmission, the cost which then takes the place of the coal cost must be usually much less, or the water power would not be employed, and this means that the cost which takes the place of the coal cost at the air driven machine is also less that it would be if steam was employed to drive the compressor, or it would be less than the equiva-

lent of 15 pounds of coal per horse-power hour.

It is concededly impossible to generate steam at a central station and to transmit it by piping to the several machines to be operated, as we do transmit the air, on account of the constant heat radiation of the line and the consequent losses of condensation, besides the trouble caused by expansion and contraction of piping, water hammer, etc., the necessity of providing arrangements for trapping or disposing of the water of condensation, and, in spite of all precautions, the frequent stoppages for repairs entailed. Each steam operated machine, therefore, must have its own boiler and all appurtenances, its own supply of fuel and water. Such isolated and intermittently operated machines, taking the day through, cost in coal actually consumed at least 30 pounds and often much more per horse-power hour of work actually done, or about twice as much as the coal cost of the air operated machines.

With the air driven machine, when the air is piped to it, that ends it, and the operator has only to manipulate the throttle and attend to the lubrication. With the steam driven machine there is not only the cost of the coal actually consumed, but there is also the bringing of the coal to the machine, the supplying of the water, the firing and caring for the boiler, with all which that implies, so that there is for each machine the labor of a man or at least the equivalent of one man's labor to be added to the cost of operating.

The equivalent in coal cost of a man's labor is worth considering. Say that coal costs at the machine $4. per short ton. Then if the man's wage is $2 per day that will be 1,000 pounds of coal, or 100 pounds per hour, and for 10 horse-power, which is a big allowance for a hoisting engine, this would be 10 additional pounds of coal cost per horse-power hour.

So far, then, as the actual cost of the power used is concerned there is evidently a great saving in the employment of air instead of steam, and on this account alone it is no wonder that the knowing ones choose the air transmission even when there are no special conditions as in mining, tunneling, subaqueous work, etc., compelling them to do so.

In addition to the saving in coal cost there are other advantages which air carries with it. In the use of steam there is the time taken to fire up and get the pressure before work commences, there is the warming up process and the working of the water out of the pipes and cylinders every time the machine is started up after standing, none of which delays occur with the air, so that in constant readiness and instant realization of power to the utmost limit required the air will every day put in from 10 to 25 per cent. more actual work per day. Stuffing boxes will give no trouble, water will not knock out cylinder heads, pipe joints will not be giving out, there will be no chance of low water in the boiler, no burning of flues or crownsheet, no possible blow up. The cost of repairs and maintenance will be much less and the certainty of continuous readiness for work will be much greater. While, as was said, the air driven machines are identical with the steam driven type, the individual boilers and all their appurtenances are dispensed with, the cost of them, as far as it goes, helping to offset the larger costs of the compressed air installation as a whole. The saving in repairs and maintenance with this reduction in the cost of the air operated machines may go to offset the fixed charges entailed in the larger cost of the compressors and piping.

The installation and operation of a complete economical and reliable compressed air plant calls for no extraordinary reach of knowledge or skill, but it does demand thorough and conscientious engineering. The things which are worth while and which will guarantee satisfactory results are to be insisted upon. Excellent apparatus is provided by the makers of that class of machinery if demanded. In mechanical lines there are no more creditable records than those of modern air compressors employed in the larger and more responsible engineering work.

In driving the tunnels under the North and the East rivers at New York, the compressors ran without interruption, maintaining constant air volume and pressure for months, the lives of men dependent upon their continuance, and they never failed. If good machines are selected, and they are properly installed and connected, there will be no cause for complaint or disappointment. The earlier employments of compressed air were more or less of a temporary or experimental character, and many things were permitted which long

discredited compressed air practice. There is no excuse for this to-day.

The steam engine element of the steam driven compresor, is in no essential, different from the sationary steam engine, and it has the advantage of a practically constant load per stroke, so that the relative and actual sizes and capacities of cylinders may be selected with close adaptation to the work to be done. The details which secure accuracy of working are sufficiently familiar.

High pressure steam, with or without the refinement of super-heating, compound cylinders and condensors are the essentials, not all of which can be always insisted on; then the compression of the air should be two-stage with efficient intercooling and after-cooling.

With respectable compressors secured and installed, the valves and connections and piping should correspond. There is no excuse for leakage, and there should be no opportunity to talk about it. Steam has the advantage that it can tell of its leaks and insist upon their avoidance, so when first-class steam piping is required it can be laid and connected so that there can be given an almost positive guarantee that there shall be no leak when the steam is turned on, and if a leak is revealed it is more or less a reproach to the workman or the supervising engineer.

If piping can be laid perfectly tight for steam, it can be laid as tight and reliable for air, for what will suffice for the one will be quite as satisfactory for the other. In fact, as the air pipes are not heated and cooled and expanded and contracted as steam pipes are, it is easier to make them tight and to keep them so, and this is practically demonstrated and enforced by the excellent piping throughout the installations at Crescent and at Lock 7, where those in charge assured the writer that the leakage losses were inappreciable. When rock drills are driven by air, with hose connections, some leakage may occur, but even here it is almost entirely preventable. There is a certain quarry of large extent in Ohio which is operated entirely by compressed air from a central plant, and which is so perfectly piped and so carefully looked after, that when the compressors are stopped the pressure is maintained in the pipes all night.

To an engineer familiar with the running of hoisting engines and the usual types of machines employed for out door service and driven by steam from the boilers to which they are tied, the use of air for the same purpose comes as a pleasant experience. The instant readiness of the air and the lively movement of the machine at once is so different and such a relief from the sluggish action of the steam. There is no waiting for the cylinders to heat up, and no watching of pet cocks to save the cylinders. The hand or the bare arm can come in contact with any part without fear of burning.

This is the universal experience in the use of compressed air for power. There is, however, one familiar accompaniment of inconvenience in the accummulation of moisture in the air pipes and the choking and freezing up of the exhaust pipes in consequence. This is, of course, an objectionable feature, and at first might be urged as even without remedy, but later practice has minimized if not abolished this trouble.

There is no way of securing dry free air to begin with. All air contains a considerable percentage of moisture, so that after the air is compressed into much smaller volume, it is then saturated, and more than saturated, with moisture, so that water begins to be dropped in the pipes as it flows along and ultimately may make trouble in the drill or engine where the air is used. The simple remedy is to allow the air to deposit its moisture and then to draw the water off before it comes to the machine.

When the air is at its highest pressure and its lowest temperature, its saturation point or its capacity for carrying moisture, we might say as a part of itself, is at the lowest, and then if it has the opportunity it will give up so much of the moisture that what remains will not be heard from. It is the almost universal custom when a compressor is installed, to place an air receiver quite close to it, and all the air compressed first passes through this receiver. The receiver is provided with a drain cock, and the engineer is instructed to occasionally open this and draw off the water. But really very little water is ever found here. Some oil and dirt, originally impalpable dust in the air, will accumulate and this it is proper to get rid of, but the air has not got ready to release and deposit the moisture, because as it passes through this receiver it is still hot with the heat of compression.

When the air passes through pipes of sufficient length to thoroughly cool it, if there is then provided another receiver or other opportunity for depositing the moisture, with means for drawing it off, always remembering that water runs down hill, then the air will be sufficiently dried for use without annoyance.

Outside the compressor house at Crescent there is a large horizontal receiver with valves and piping for distributing the air in the different directions required. Here, as usual, there is a drain cock, but little or no water can be drawn from it. One air line from this compressor runs more than a quarter of a mile to two three-drum hoisting engines used for loading crushed stone upon boats in the Erie Canal. It happens that it is sometimes desired to run these hoists when the compressor is not in operation, and so a steam boiler has been placed in position with all the necessary connections. When the air is in use this boiler becomes an air receiver, the air passing into it and then through the connecting pipes to the hoists, the same pipes and valves being used for either the air or the steam. As the air comes to this boiler or receiver cooled by its journey through the pipes, it is here in position to deposit its moisture and here the water is found, and the hoisting engines are run without trouble. When steam is used the air supply pipe is shut off and the boiler is filled to the proper height with water.

The better way after all is to drain the air as completely as possible immediately after the compression. A fine example of advanced modern practice is offered in the compressed air plant for the Rondout siphon of the Catskill water supply for New York City. Here there is an immense job of shaft sinking and tunneling, the compressors to be used being ten Ingersoll-Rand Imperial Type X Corliss, compound condensing steam and two-stage air, the air pressure being maintained at 110 pounds.

There are here as usual, air receivers near the compressors, one large receiver for each pair of compressors, but directly connecting with each receiver is a large intercooler through which the air must pass and be cooled to normal temperature before entering the receiver. This provides the conditions of highest pressure and lowest temperature for the air, so that it cannot fail here to drop superfluous water, which, therefore, can cause no further trouble when the air is finally used.

As the lowering of the temperature of the air, whether artificially compressed or not, also lowers its moisture capacity, and as the temperature of the air is lowered in the act of doing work, the principal trouble resulting from the released moisture occurs in the exhaust passages of the engines or drills, these sometimes freezing up, and to remedy this the obvious device has been suggested, and in some cases adopted, of heating, or reheating, the air immediately before using. This is an undoubted success, but there is as yet no such extension of the practice as might be expected. The reheating of the air has the additional advantage of considerably increasing its volume at very slight additional fuel cost, making it possible to do say 20 to 25 per cent. more work with a given air consumption, or to maintain a given rate of work upon a proportionately reduced air consumption.

At Lock No. 7 a number of home made,—made in the machine shop of the works—reheaters are employed with satisfactory results. For obvious reasons the advantage of the reheater is not so pronounced where the machines are only operated occasionally on intermittently, as where the running is continuous. The reheating of the air for the engine which drives the machine shop and blacksmith shop at that place is a good example of the profitable application of the principle.

Compressed air makes its way and extends its field of employment upon its merits, and we may confidently expect to see it more generally employed for machinery normally steam driven, as it is upon the Barge Canal.

For use as a secondary-power producer in shaft sinking, the most satisfactory machine yet devised is the simple straight-line air compressor. This type of machine shows greater efficiency than the general run of small engines. A 16x 16¼x18-in. compressor will be found sufficienty large to operate three or four drills and a pump in sinking a shaft of moderate depth. Compressed air has so far been found more satisfactory than electricity as a secondary-power in shaft sinking. —*Engineering and Mining Journal.*

FORMULAS RELATING TO AIR LIFT PUMPING

In the "Zeitschrift des Vereines deutscher Ingenieure," of April 3, 1909, Herr H. Lorenz discusses mathematically the working of air lift pumps and derives the following equations which may be used in their design.

According to Herr Lorenz the maximum capacity for a given pump is attained when

$$p_0 [\log_e(p_1/p_0)]/V_w G_w = (1+f_2)(V_a+V_w)/g A^2, \quad (1)$$

or, eliminating pressure from the equation, when

$$(1+f_2)(V_a^2 - V_w^2) = 2 g h A^2 + f_1 V_w^2 \quad (2)$$

In (1) and (2)

p_0 = atmospheric pressure in lbs. per sq. ft. = 2,116.3.

p_1 = initial pressure of air supply in lbs. per sq. ft.

V_w = flow of water from upper end of pipe in cu. ft. per sec.

G_w = weight of 1 cu. ft. of water = 62.43 lbs.

f_1, f_2 = resistance coefficients of pipe.

V_a = air supply in cu. ft. per sec. (at atmos. pressure).

A = sectional area of delivery pipe, in sq. ft.

g = 32.2.

h = distance from water surface to level of delivery, in ft.

Example.—Assume a well of, say, 8 ins. diameter, and that 0.25 cu. ft. per sec (about 112 gals. per min.) is to be lifted through a height h = 50 ft. The internal diameter (D) of the delivery pipe is 3 ins. (0.25 ft.), and its total length L = h + submerged portion (h_1) is taken for preliminary calculations equal from 2.25 h to 2.5 h, say 120 ft.

According to Herr Lorenz, the resistance coefficient $f_2 = 0.02$ L/D, and in this case = 9.6; also f_1 may be taken equal to 2.

Since $A = \pi D^2/4 = 0.7854 \times 0.0625 = 0.0491$ sq. ft., the maximum entrance velocity (v) of the water into the bottom of the delivery pipe $= V_w/A = 0.25/0.0491 = 5.09$ ft. per sec. From (2), with the values now known, $V_a = 0.898$ cu. ft. per sec. $= 3.59\ V_w$.

Solving (1) now, it is found that $\log_e(p_1/p_0) = 1.156$; whence p_1, or the pressure of the compressed air $= 3.18 p_0 = 46.7$ lbs. per sq. in., absolute.

For determining the proper length h_1 of the pipe which must be submerged, Herr Lorenz gives the following equation:

$$h_1 - (p_1 - p_0)/G_w = v^2 (1 + f_1)/2 g \quad (3)$$

Substituting in this equation, and remembering that p_1 and p_0 are to be expressed in lbs. per sq. ft., and that v = 5.09, h_1 is found to be 75.1 ft. (assumed above as 120—50 = 70 ft.).

The efficiency of the air lift is equal to the work done in lifting a given weight of water through h, divided by the work required to compress the air needed to effect the lift of this quantity of water. It may be obtained from the equation:

$$\text{Efficiency} = V_w G_w h/V_a p_0 \log_e (p_1/p_0) \quad (4)$$

or, in the present example,

$$\text{Efficiency} = 0.25 \times 62.43 \times 50/0.898 \times 2{,}116.3 \times 1.117 = 780/2{,}196 = 36\%.$$

The efficiency constantly decreases with increasing air supply, while the flow of water rapidly rises with increasing air supply to a maximum, and then gradually falls.

In the present example about 85% of the maximum flow can be obtained with about half the air supply, and at an efficiency of about 60%.

In "The Canadian Engineer," of April 9, Mr. O. W. Smith, Assoc. M. Can. Soc. C. E., gives particulars in regard to two air lifts used in connection with the water supply of Palmerston, Ont. These wells are 8 ins. in diameter, and the air lifts in them consist of 5-in. eduction or delivery pipes, inside of which are 1½-in. air pipes.

According to one of the tests made 225 gals. per min. were lifted in each pipe through a distance of 39 ft., 0.38 cu. ft. of free air being required per gallon of water lifted; the air pressure was 31 lbs. per sq. in. gage.

Referring to equation (4) these values can be expressed as follows: $V_w = 0.5013$ cu. ft. per sec.; $V_a = 1.425$ cu. ft. per sec.; h = 39 ft.; p_1 = 31 lbs. gage. = 45.7 lbs. abs.; $p_1/p_0 = 3.11$; $\log_e (p_1/p_0) = 1.134$. Substituting in (4) the efficiency is found to be 35.7%.

According to the preceding equations of Herr Lorenz, however, the discharge of each of these lifts may be more than doubled, working with the same air pressure and at the same efficiency.

From (3) the submerged length of pipe $h_1 = (p_1 - p_0)/G_w$, approx. $= 2.11 \times 2116.3/62.43 = 71$ ft. $\therefore$ L = 39 + 71 = 110 ft. Withdrawing the air pipe from inside the delivery pipe and placing it outside, D = 0.4204 ft. $f_2 = 0.02 \times 110/0.4204 = 5.233$. A = 0.1389 sq. ft.

Substituting in (2), and remembering that for the same efficiency 1 gal. water is to be lifted with 0.38 cu. ft. of air (making $V_a = 2.842\ V_w$), it is found that $V_w = 1.0724$ cu. ft. per sec. = 481.3 gals. per min., or 2.14 times the quantity discharged in the test.

It is asserted by the U. S. Geological Survey that the Great Salton Sea, forty miles long and fifteen miles wide, which was formed by an irruption of the Colorado river, will disappear entirely by evaporation in about fifteen years.

THE AIR-STEAM ENGINE

The air-steam engine, shown in Fig. 1, was built and tested in the shops of the Iowa State "College of Engineering" at Ames, Iowa. The complete tests were first made with steam alone and then the same engine was tested with the air-steam mixture. The long line of tests proved conclusively the greater economy of the mixture, and further demonstrated the fact that the percentage of saving depends upon the ratio of air and of steam in the mixture. The larger ratio of air and smaller ratio of steam gave the greater economy and saving.

Fig. 2, illustrates the chief constructive features of the "Christie Air-Steam Locomotive." The four cylinders are all of the same dimensions, two in tandem on each side. The valve gear is so arranged that the front and the rear cylinders produce the working strokes alternately, and the operation for each cylinder is a four-stroke-cycle, as follows:

First stroke: The cylinder fills with atmospheric air taken in through the air-inlet valve.

Second stroke: Compression of the air in the cylinder clearance.

Third stroke: Introduction of steam into this compressed air down to the point of cut-off, then expansion of the mixture to the end of the stroke, this stroke doing the work.

Fourth stroke: Exhaust of the spent mixture.

The following explanation of the principle of operation of the air-steam engine is furnished by Prof. E. J. Christie, its inventor:

THE PHILOSOPHY OF THE AIR-STEAM MIXTURE.

When the air in the cylinder has been compressed to approximately the same pressure and temperature as that of the saturated steam in the boiler, and the steam then introduced into the cylinder with this compressed air down to the point of cut-off, the resulting mixture is highly superheated.

When a cubic foot of saturated steam A, Fig. 3, at 150 pounds absolute pressure, and its corresponding temperature of 358.3 degrees Fah., is mixed with one cubic foot of compressed air B, at the same absolute pressure and temperature, (by breaking away the partition between the two) it is self-evident that the temperature of the resulting mixture will remain the same, 358.3 degrees, and the pressure 150 pounds absolute. But this now is a high degree of super-heat. Clearly, the pressure of the mixture is 150 pounds absolute, as before, but, according to the second of

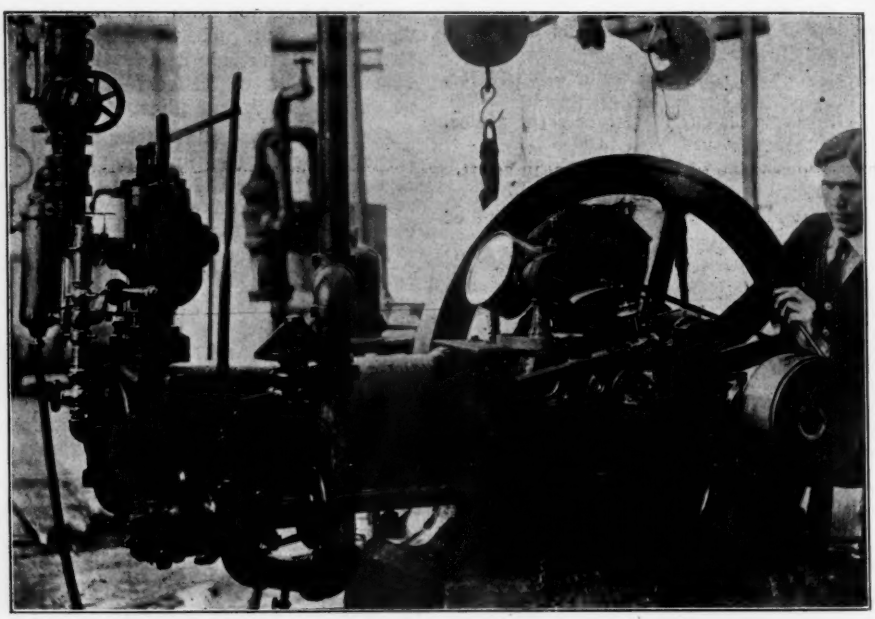


FIG. 1.—AIR-STEAM ENGINE AT IOWA STATE COLLEGE.

Dalton's laws, this 150 pounds is made up of 75 pounds steam pressure and 75 pounds air pressure.

"The pressure of a mixture of a gas and a vapor is equal to the sum of the pressures which each would possess if it occupied the same space alone."

of air alone and of steam alone at 50 pounds absolute pressure and 280 degrees temperature respectively, the final temperature of the steam alone would be 150 degrees *above* zero, while that of the air alone would be 165 degrees *below* zero, the difference being 315 degrees.

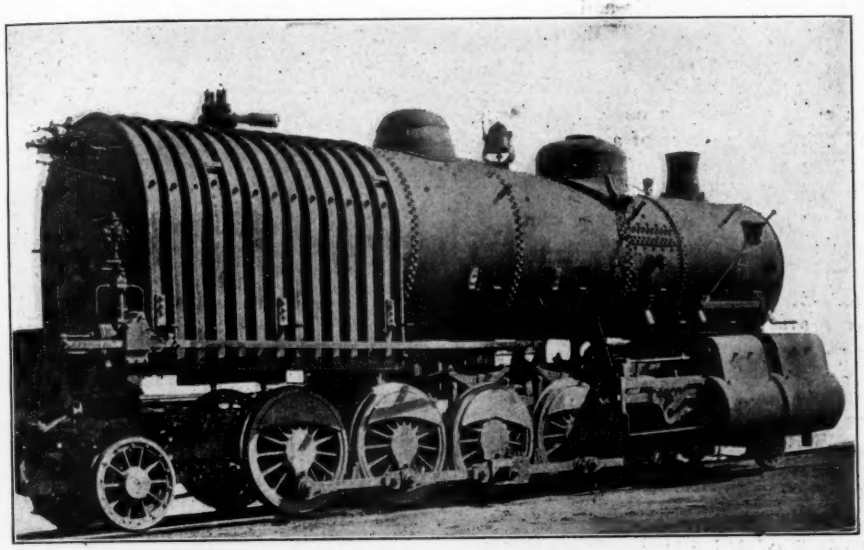


FIG. II.—AIR-STEAM LOCOMOTIVE.

If this 150 pounds mixture, (75 pounds air and 75 pounds steam), was just saturated, the temperature would be the same as that of 75 pounds steam, or 307.4 degrees Fah. But the temperature of the initial mixture is 358.3 degrees Fah. The difference between 358.3 degrees and 307.4 degrees, saturated, is 50.9 degrees of super-heat.

A larger proportion of air and a correspondingly smaller proportion of steam in the mixture will produce a greater degree of superheat. Hence the importance of securing the *proper ratio* for the greatest economy.

UTILIZATION OF MORE OF THE LATENT HEAT OF THE STEAM.

The latter and greater portion of the expansion in the running of the engine is performed with the saturated mixture. When a saturated mixture of steam and air expands adiabatically, performing work, there is a heavy transfer of heat from the steam to the air in the mixture. Thus, in ten expansions

If this initial cubic foot of steam and this initial cubic foot of air were intimately mixed, and then, performing work, expanded adiabatically to the same extent, at the end of the expansion it would be utterly impossible

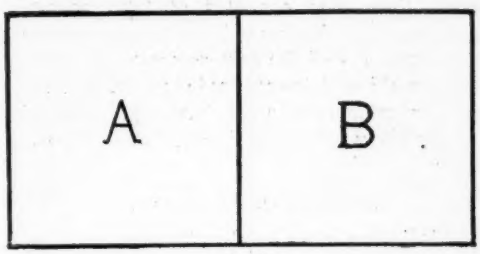


FIG. III.

for the air to sink to the frigid temperature of 165 degrees *below* zero while the steam in the mixture retained the temperature of 150 degrees *above zero*. It must follow that the air can not grow so extremely cold while intimately mixed with this very hot steam, but instead, the steam transfers heat to the air

in the mixture during the entire period of expansion.

In a saturated mixture, this transfer of heat from the steam to the air in the mixture, is clearly a transfer of the *latent* heat of the steam, and it is the same latent heat which otherwise is lost in the exhaust steam of the present steam engine.

In a proper mixture of air and steam, fully 50 per cent. to 60 per cent. of the latent heat of the steam can be utilized.

The chief merit of this system is that it has the effect of giving a non-condensing engine all of the advantages of a condensing engine without the necessity of a condenser and without water for condensing purposes.

Lastly, cylinder condensation is almost totally avoided by the high temperatures of air compression and the high super-heat of the mixture. On the average, the total avoidance of this great loss of cylinder condensation means 50 per cent. more work with the same steam and the same fuel.

TURBO COMPRESSORS*

By C. Regenbogen.

The first practical rotary air compressor was built by Rateau in 1906, and is interesting because, in addition to being a turbo compressor, it is driven by an exhaust steam turbine taking waste steam from reciprocating engines. This compressor delivers air at 105 lb. pressure, and has been in constant service since 1906. The compressor proper was built in four separate stages, with intercoolers between them, and consisted of two separate machines, each having a low pressure turbine and two stages of the compressor on its shaft. This machine delivered 3180 cu. ft. of free air per minute at a discharge pressure of 105 lb. gauge when running at 5,000 rev. per. min.

MECHANICAL EFFICIENCY.

This is the ratio of the diagram areas of the air and steam cylinders. Since compression in an air cylinder takes place along a line between the isothermal and the adiabatic this efficiency is considerably higher than if it were referred to the work of isothermal compression, inasmuch as it takes into account only the loss between the two cylinders. To compare the relative efficiencies of reciprocating and rotating compressors, it is necessary first to define an efficiency which will be equally applicable to both cases. The best solution of the problem is considered the one that refers efficiency to isothermal compression, because this is the ideal to which our efforts are directed.

Attention is called to another possible error. The thermal efficiency of an air compressing machine is determined by the relation

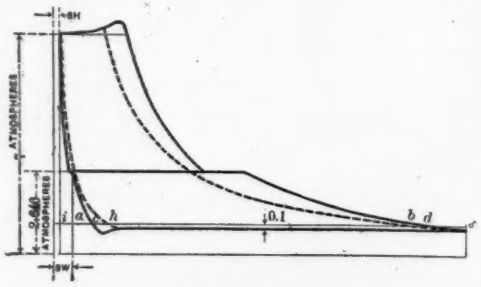


FIG. I.—THEORETICAL INDICATOR CARD FOR A TWO-STAGE COMPRESSOR.

between the heat energy represented in the compression cycle and the heat energy actually absorbed in the driving machine. A reciprocating engine works at its highest efficiency with a vacuum of say 25.5 in., while a turbine performs to best advantage at 28.5 and higher vacuum.

In comparing the two types of machines on a thermal basis, one must unquestionably take the lower vacuum limit as a basis, as in exceptional cases a reciprocating engine referred to 25.5 in. might give a higher thermal efficiency than a turbine referred to 28.5 in.; this would not be fair, as the turbine makes possible the obtaining of the remaining heat energy in the steam (between 25.5 and 28.5 in. vacuum), while in an engine this is a direct loss.

To avoid all possible error in determining the relative merits of the two systems, it is necessary to consider the question on the basis of production costs, which consist of steam consumption, cost of installation, depreciation, interest, upkeep, attendance, lubrication, relative condenser requirements, &c. Another source of difficulty arises in deter-

*Abstract of *Iron Age* translation of a paper before the German Blast Furnace Association.

mining the air quantity discharged by the two types of machines. Here enters an uncertainty of the accuracy of the results given in published tests of reciprocating machines.

METHODS OF MEASURING AIR QUANTITIES.

Fig 1 represents an air diagram. The relation $\frac{cd}{ae}$ gives the volumetric efficiency which, multiplied by the piston area and number of revolutions per unit of time, gives an approxi-

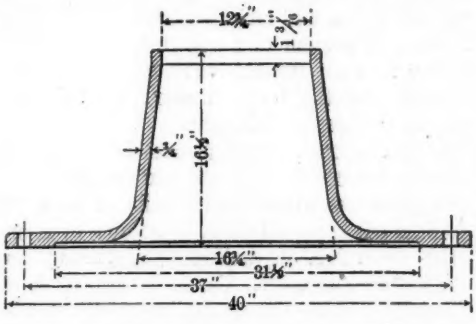


FIG. II.—NOZZLE WITH ORIFICE FOR MEASURING AIR DISCHARGE USED AT ROTHE ERDE.

mation of the volume delivered. It is only approximate because it depends upon the tightness of the valve gear and the time of its opening and closing with respect to the piston travel, as well as upon the influence of the heating through the inlet valves and cylinder walls and the mixing of the free air drawn in with the air of the clearance space, &c. Inaccuracies are introduced here that have a considerable bearing on the final efficiency.

Since the main point of interest lies in the quantity of air actually compressed it is considered proper to refer to the discharge pressure line. One can then work backward and determine the quantity of air taken in on the suction stroke as indicated by the dotted line in Fig. 1.

When a gas flows from one space to another of lower pressure, it assumes a certain definite maximum velocity, provided the lower pressure lies within the limits known as the critical pressure. This velocity is called the critical velocity, and is comparatively easily determined. If one allows the compressed air to flow through an orifice (Fig. 2) of definite size into a space in which the back pressure is not allowed to exceed the critical, then the quantity of air that passes through the orifice in a unit of time is quite definite, and for every size of orifice there corresponds a certain definite air quantity for every initial pressure. If it is impractical to allow the air to escape or if a high enough drop in pressure cannot be obtained, it is still possible to measure air velocities through orifices. By introducing a throat or orifice in the path of an air flow and measuring the pressure difference on either side of it, the velocity through the orifice can be calculated by the formula

$$h = \frac{v^2}{2g} = K \frac{p}{p_1}$$

from which, when the orifice size is known, the air quantitiy is determined in the simplest way.

Some object to rotating compressors, claiming them to be uncertain on account of their slip. The application of the method of air measurement just described presents a means of being certain that the machine is actually compressing air and not merely whirling it. When no air is discharged the velocity through the orifice is zero and likewise the pressure difference zero. Now if one permits this pressure difference on each side of an orifice to affect the control of the machine in such a way that with decreasing quantity of air discharged

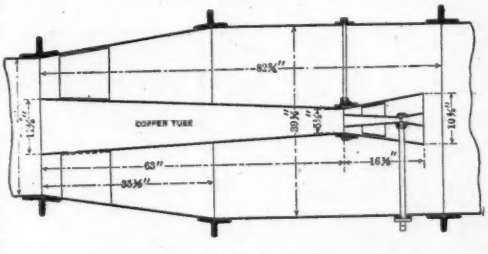


FIG. III.—COMPOUND ARRANGEMENT OF ORIFICES FOR AIR MEASUREMENT.

the machine gains speed and in turn develops a higher pressure, the objection is removed that can be raised to turbo blowers for blast furnace work. The machine will increase speed and concurrently its discharge pressure up to the limit of its capacity.

To obtain a high enough pressure difference for this method of governing without excessive throttling, several orifices are introduced into one another, as per Fig. 3. In the outside

orifice there is a small pressure corresponding to the higher velocity. The difference between the pressure in the main and the pressure in the inside orifice is considerable and affords reliable governing. This pressure difference acts on the spring loaded piston shown in Fig. 4, and shifts the fulcrum of a lever, on one end of which is attached the governor, on the other the inlet valve of the driving machine.

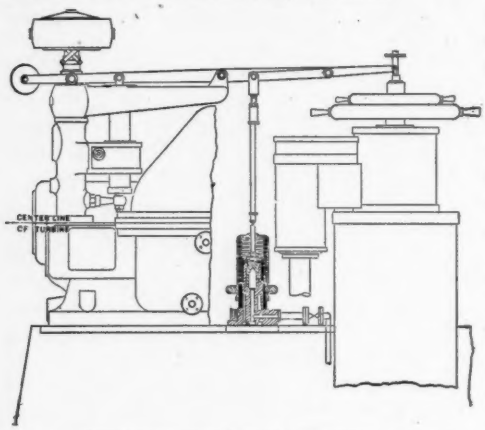


FIG. IV.—GUTEHOFFNUNGSHUTTE PRESSURE REGULATOR.

When a turbo blower is thus governed interruption of air discharge with a hanging furnace is impossible. The steam turbine must be large enough to develop the maximum energy required at any time, just as the steam engine of a piston blowing engine. A turbo blower at constant speed will deliver an almost uniform pressure. Difference in output can be obtained with constant speed by the introduction of a throttling valve, and in this respect lies a salient advantage of the turbo blower. Within certain limits any desired pressure can be obtained at any volume of discharge.

The work done by the driving machine can best be determined by measuring the heat quantities, which are taken up by the air, the cooling water, the outside air, the oil on the bearing, etc. The calculations can then be carried out in a simple way by the equation

$$dQ = di - Av.\ dp.$$

Since the decision as to the advisability of installing one or the other type of power machine generally resolves itself into considerations of operating cost, it would be pertinent to consider this phase of the question. Since the gas engine and reciprocating blower, in the absence at present of a gas turbine, are competing in blast furnace work with the steam turbine and the turbo blower, consideration will be confined to this case.

In the technical press articles in which the relative operating costs are shown for steam and gas driven machines, the value of the blast furnace gas is placed either at nothing or at an arbitrary value, depending upon the system the author advocates. On such premises it is possible to show one or the other case to advantage at will. In plants so located that the surplus gas cannot be converted into a saleable by-product to outside consumers, and having sufficient quantities of gas to satisfy all requirements, the gas has no value, because it has no market. Should it possess a market value, which value is generally estimated on the basis of the heat value of the gas in comparison with the heat value and cost of coal in the particular vicinity, it becomes a question whether gas should be burned in hot stoves or sold and the air blown heated in some other more economical manner. Apparently no one has ever valued the gas burned in the hot stoves higher than its cleaning cost. The gas

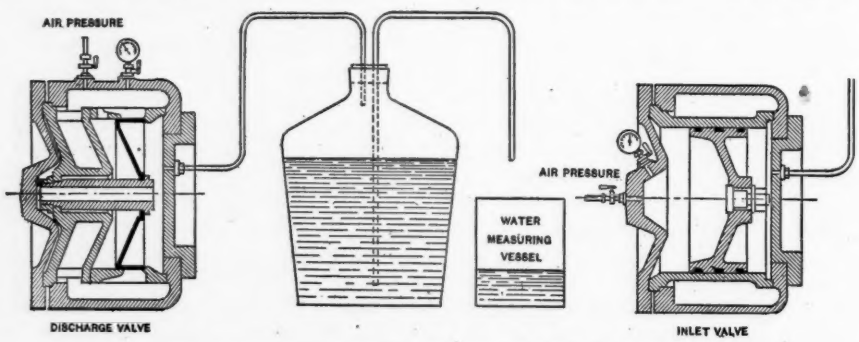


FIG. V.—ARRANGEMENT FOR TESTING TIGHTNESS OF VALVES.

is a by-product incidental to the making of pig iron, and that not burned in the hot stoves or converted into energy must be wasted. Only when it is possible to utilize to advantage all the energy that the gas possesses when used in the most economical manner can the gas have a value placed upon it, and then only on

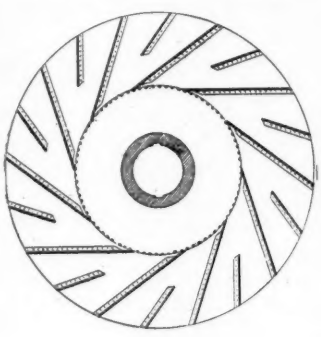


FIG. VI.

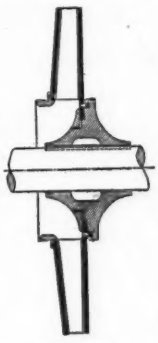


FIG. VII.

the basis of the prevailing prices for electric energy, compressed air or the gas itself (if it is sold or used in its original state) in competition with other sources of energy.

Therefore, in very many cases, particularly in isolated blast furnace plants, the question of whether steam or gas drive should be adopted should be carefully considered. Always where sufficient gas is available for a long time to come, to satisfy the requirements of the plant, steam drive is undoubtedly to be preferred. Where a value can be placed on practically an unlimited quantity of energy, gas engine drive is certainly in order. Where part of the energy is developed by gas fired boilers, a serious study of the situation will guide one to steam turbine drive, where formerly fashion (one cannot call it anything else) or an overestimated evaluation of the merits of gas drive, pointed to gas engines.

IMPROVEMENTS IN RECIPROCATING COMPRESSORS.

Since scientific investigation of the influence of various conditions on the efficiency of piston compressors has been guiding designers, the principal parts of the air cylinders, especially in large machines, have undergone considerable change. Now provisions are found for taking air into the cylinders at as low a temperature as possible, combined with the most elaborate arrangements for cooling. Radial slide valves in the air heads have been almost entirely eliminated in recent designs. Only with the most careful machine work and accurate fitting and grinding is it possible to get the sliding grid valves tight under the temperatures at which they have to work. Poppet valves or these in conjunction with slide valves are now found on air compressors, although there are good compressors having either only poppet valves or only sliding valves. High

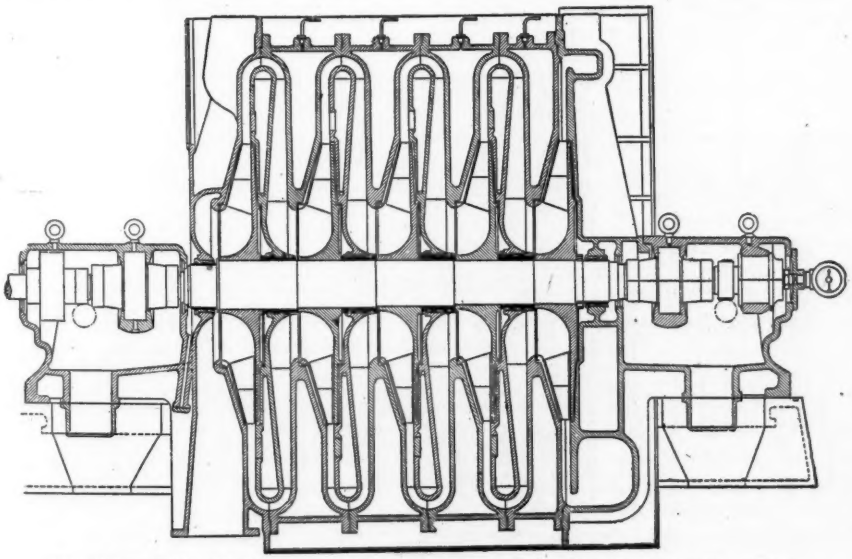


FIG. VIII.—AXIAL SECTION OF A FIVE-STAGE GUTEHOFFNUNGSHUTTE-RATEAU TURBO-BLOWER.

speeds likewise have firmly established themselves in compressor work, making electric drive quite suitable.

What influence valve gears have on efficiency has been brought out in a general way in the discussion of air quantity determinations. Fig. 5 shows arrangements for testing the tightness of valves and valve seats. Compressed air is applied above the valve, and any leak passing the seat is allowed to pass into the bottle, from which the rate of water escape into a measuring vessel can be determined.

Compression takes place in turbo compressors in a similar way to that in centrifugal pumps. In a series of impellers free air is compressed to the desired final pressure. Figs. 6 and 8 show the cross and axial sections of an impeller with straight blades (Gutehoffnungshütte-Rateau). Fig. 7 shows an impeller of the Jäger type, while Fig. 8 shows the type used in blast furnace work (Gutehoffnungshütte-Rateau) having a capacity of 42,400 cu. ft. per minute.

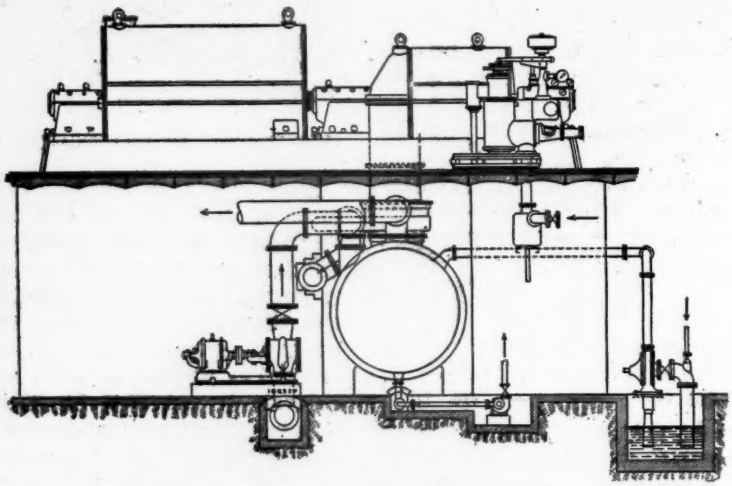


FIG. IX.—ELEVATION OF AN INSTALLATION OF A STEAM TURBINE DRIVEN ROTARY AIR COMPRESSOR.

Unfortunately the construction of electrically driven blowers is limited by the alternating current motor. One is tied, so to speak, to

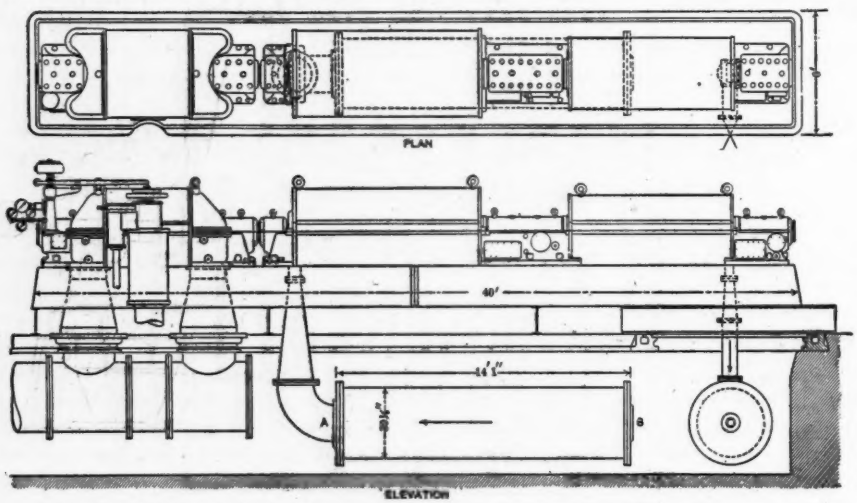


FIG. X.—PLAN AND ELEVATION OF A TESTING ARRANGEMENT IN THE WORKS OF THE GUTEHOFFNUNGSHUTTE.

1500 or 3000 rev. per min. by the frequency of the alternating current, and considerable inconvenience is encountered in an attempt at variable speed which latter, however, has been recently made possible by Brown-Boveri's special transformers. Where variable speed is impractical air regulation has to be effected by suction or discharge throttling, although blast furnace work, being very constant in its character of load, requires very little adjustment.

Any desired regulation, however, can be obtained without any difficulty whatever with steam turbine drive, which lends itself admirably to this particular service. Fig. 9 shows such a machine, having a capacity of 42,400 cu. ft. of free air per minute.

ARRANGEMENTS FOR TESTING TURBO COMPRESSORS.

Fig. 10 is a sketch of a specially built arrangement for experiments on steam turbine driven compressors. The boiler plant supplies steam direct to the turbine if a high pressure

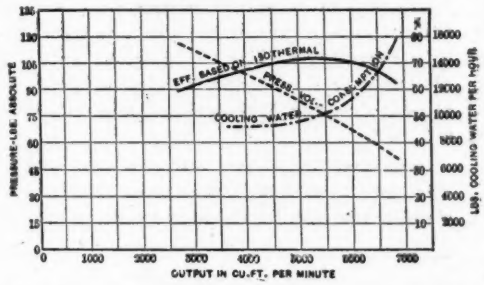


FIG. XI.—TEST CURVES OF A TURBO-COMPRESSOR BUILT BY THE GUTEHOFFNUNGSHUTTE.

machine is being tested, or to a feed water heater if an exhaust machine is under investigation. In the latter case steam enters the heater throttled and, therefore, superheated. In passing through the water the steam loses its superheat and emerges in the form of moist steam at about atmospheric pressure, approaching actual exhaust steam conditions in practice. A surface condenser supplies the required vacuum for the turbine. The condensed steam is weighed in two tanks in the customary way.

For measuring the air quantities a long receiver of large cross section, in the outer head of which is placed a suitable orifice, is connected to the suction inlet of the compressor. Pressure readings are taken with carefully calibrated inclined water columns and the tempeature determined with precision thermometers. The suction inlet of the compressor proper has a gate valve to adjust the inflowing air quantity. At the discharge end of the compressor another gate valve affords means of obtaining the required discharge pressure. Next to this valve is a large receiver with several perforated partitions in it, which destroy any eddies in the air which would affect the accuracy of the measurement. At the end of this receiver is another orifice through which the air escapes to the atmosphere. This latter orifice serves to measure the quantity of air actually compressed. The cooling water for the jackets and bearings is measured in both quantity and temperature rise. The heat lost to the surrounding air has not been determined up to the present, as the compressors are so efficiently water jacketed that this is too small to detect, and is, therefore, neglected.

For K in the equation, 0.98 is used. Fig. 10, where the entire air testing arrangement is illustrated, shows a compressor of 4,700 cu. ft. per minute capacity, 90 lb. gauge discharge, driven by an exhaust turbine running 4,000 rev. per min. Three such machines have already been built and the test results obtained are highly gratifying. Of all steam users the exhaust turbine is most suited to get the maximum mechanical energy out of the steam up to the highest attainable vacua of to-day. When one considers that the exhaust turbine can convert into mechanical energy the steam that in many cases is allowed to escape, and generate from it electric and compressed air power, it would seem that the exhaust turbine as an economic consideration is far in advance of all other machines. Estimates of operating costs in such cases would give surprising figures in favor of the rotating machines.

Unfortunately any great number of definite figures from reliable tests of turbo blowers are not yet available. The difficulties that were to be surmounted lay, not only in the details of construction of the machines, but also in the designing and making of suitable means for testing. The following, however, gives some figures and curves of tests made on the 4,700 cu. ft. per minute compressors built by the Gutehoffnungshütte. One of these has already been accepted and has been put into regular service.

The curves in Fig. 11. show the perform-

ance of this machine at a constant speed of 3,600 rev. per min. The conditions of the test were very unfavorable, as there was not sufficient cooling water. Subsequent tests made when sufficient water was available showed that it was possible to cool the air at the various stages to inlet temperature and lower. The cooling water quantities flowing through the jackets were very carefully determined, as well as the temperature

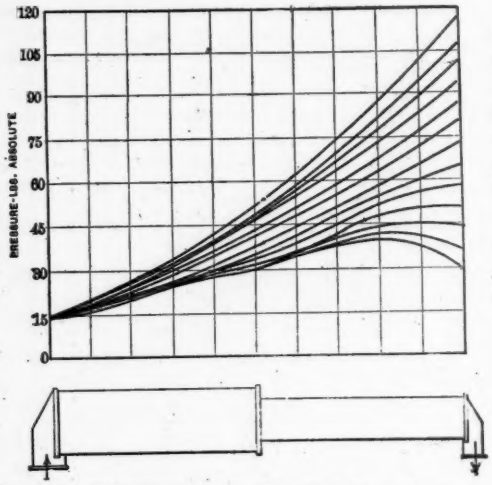


FIG. XII.—DISTRIBUTION OF PRESSURE IN A TURBO-COMPRESSOR AT DIFFERENT FINAL PRESSURES.

rise of the water and the air. Air quantities discharged by the compressor were determined by the methods outlined above.

The trial was carried out over a range of pressures from 15 to 105 lb., while the volumes displaced adjusted themselves as shown on the pressure volume curve of Fig. 11. The efficiencies shown are referred to the isothermal basis and represent the ratio of work actually applied to compressor coupling to the minimum required for isothermal compression of the quantities actually compressed. The temperature rise of the cooling water on the bearings was not determined, but was quite extraordinarily low. It can be safely said that the mechanical efficiency of the unit is not lower than 98 per cent. Other tests made have shown still better results, especially when larger quantities of water were at hand.

The curves in Fig. 12 show the pressure distribution in the various stages of the machine at final pressures ranging from 15 to 105 lb. gauge at a constant speed of 3600 rev. per min. Up to 45 lb., absolute, most of the compression takes place in the first stage of the compressor, which is diagramatically illustrated along the ordinate of the curve, and in the second part very little further compression is effected, and, in fact, in some cases an expansion takes place. Only when running at higher discharge pressures is a pressure rise obtained in all parts of the machine. At the highest pressures the second half of the machine contributes more to the entire amount than the first.

From efficiency tests made on reciprocating compressors it has been found that they consume on the average when running on 120 lb. steam pressure condensing, about 15.5 lb. per indicated horsepower hour. At a mechanical efficiency of 85 per cent. an indicated air horsepower hour is obtained on 18.5 lb. steam. The heat energy utilized by the engine compared with the heat energy of the useful work done shows an efficiency of 45 per cent.

According to reports of tests made by Julius Fürstenau, an air horsepower hour has been obtained with a blower driven by a Parsons turbine at a consumption of 16.4 lb. and a turbine horsepower hour at 14.20 lb. This consumption at 111 lb. gauge initial pressure and 28.65 in. vacuum represents an efficiency of 49 per cent.

A comparison of two reciprocating machines and one turbine compressor in the same station showed the cost of steam for compressing air

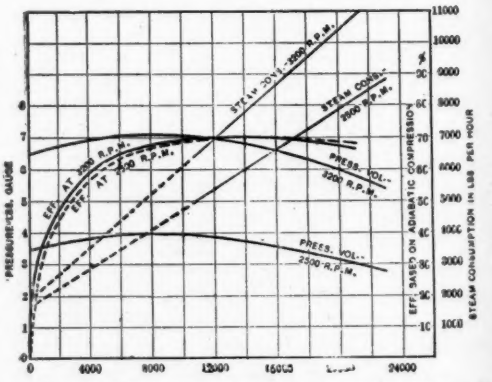


FIG. XIII.—TEST CURVES OF A TURBO-BLOWER AT MARCINELLE.

in the respective machines to be from 6 to 16 per cent. lower in the case of the turbo compressor. Exhaustive experiments on a turbo blower built by Brown, Boveri & Co. gave the results shown in Fig. 13. At Chasse where a Rateau blast furnace turbo blower is in service, efficiencies of the blower proper of from 68 to

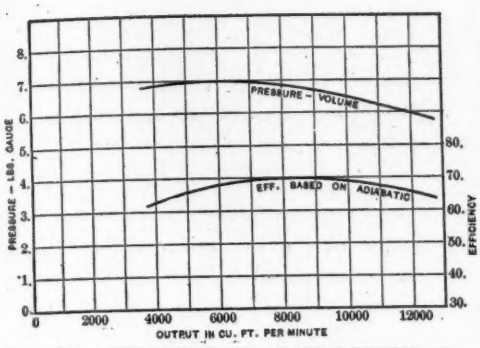


FIG. XIV.—TEST RESULT OF A RATEAU BLOWER AT CHASSE.

72.5 per cent. are being obtained, depending upon the loading. (Fig. 14.) An efficiency of 65 per cent. of the compressor corresponds to an overall thermal efficiency of 44 per cent. The tests of the turbo blowers made at Rothe Erde by K. Rummel showed a consumption of 21 lb. per effective horsepower hour and an overall thermal performance of 38 to 42.5 per cent. As evident from the figures presented, the thermal efficiencies of piston compressors do not exceed by a large margin those of rotating machines, hence the turbo compressor is in position to compete with the older form of machine.

MINE GASES; THEIR CHEMISTRY

By W. W. Tunnicliffe.

There is nothing simpler than to get at the density of a gas, as each has a definite weight and the density is always half the molecular weight. All coal, no matter of what nature, would have some quantity of fire damp in it. It is sometimes met with in cracks and crevices, and when these are cut into it issues forth as a blower. The greater proportion, however, is contained in the pores of the coal and issues from it silently or with the peculiar noise known to the miner. It is always a coal product pure and simple. It has neither color nor smell, although occasionally natural marsh or perhaps sulphuretted hydrogen.

In testing for fire damp the maximum ex- gas has apparently a peculiar smell, but this is due to the presence of other hydrocarbons plosion takes place when there is 9.38 per cent. of fire damp and about 18 per cent. of oxygen (one-fifth of the remaining air). Below a percentage of 6 of fire damp there is no explosion unless there is something else present—dust. In a very deep mine and a high atmospheric pressure an explosive mixture is found with less fire damp than was usually considered explosive. The molecules are by the increased pressure, brought closer together, and ignition is transmitted from the center where it originated. Even 2 per cent. of fire damp in a deep mine in the presence of dust from gassy coal might originate an explosion. A skilled observer is able to detect the presence of the gas when it is as low as 2 per cent. by means of a very low flame in the lamp.

The recognition of the part played by dust in explosions renders it desirable that regular determinations of the amount of dust in the air of a mine should be frequently made. This is quite a simple operation. A given volume of mine air is drawn through a tube containing cotton wool, which arrests the dust. The weight of the tube and wool should be carefully ascertained before and after the experiment, and the difference represents the weight of dust in a given volume of mine air. It is obvious that the production of heat, either by a blow-out shot or by a small explosion of fire damp, distils inflammable gases from the dust floating about. With the adjacent air those gases form explosive mixtures which ignite at the flame; more heat is produced, more gases are distilled from adjacent masses of air, these take fire, and the disastrous results radiate from the focus of the explosion entirely owing to the dust present in the air of the mine.

Carbon monoxide or whitedamp is always caused by underground fires. It shows that there is heating somewhere and is always accompanied by stinkdamp, which is met with in gobs. It is also produced by the heating of coal or shale in a gob, and analyses of mine air showing more than 0.02 of carbine oxide (carbon monoxide) are certain indications that heating is going on somewhere. In colliery explosions there is left along the track of the flame a mixture of gases which might contain enough oxygen to support life. But there is a most insidious constituent present in the shape of carbon monoxide, and it is this gas which produces fatal results.

It has been proved that the readiness of the gas to combine with haemoglobin is 300 times that of oxygen. If haemoglobin is com-

bined with whitedamp it could not combine with oxygen, and hence death speedily ensues if the air breathed contained enough of the gas. There must be no more than 5 parts present in 10,000 of air, and even then alarming symptoms sometimes ensue on any extra exertion. It is the worst gas there is to contend with and neither the lamp nor their lenses would give definite indications of it.

TESTING WITH MICE.

The greatest caution should be observed in going down inclines or through difficult places, and in putting forth exertion to return, as unconsciouness might result from the gas present in the blood. A mouse could, however, be used to detect the presence of carbon monoxide even in small quantities. It should be left for a quarter of an hour at the place where the air had to be tested, the investigator meanwhile going away. The mouse should then be killed at the spot, and by examining its blood above ground the percentage of carbon monoxide in the air could be ascertained with some approach to accuracy. Then one should prick one's finger and make a dilute solution of normal blood in two test tubes of equal diameter. The solution should be of such strength that the liquid has a yellowish tinge. The solution of the test tubes is then shaken with coal gas until the haemoglobin is saturated with carbon monoxide and the color changed to pink. In another test tube of the same diameter should be placed a solution of the mouse blood, and this solution diluted very carefully until its depth of tint is the same as that of the other solutions. Ordinary blood color is of distinctly yellow tint, but a blood solution saturated with carbon monoxide is a full pink color. Now, if carbon monoxide was present in the air breathed by the mouse the solution would be intermediate in color between yellow and pink. From the color the percentage in the air might be roughly estimated. The blood of the mouse is half saturated with .08 per cent. of CO, one-third saturated with .04 per cent., one-fifth with .02 per cent., two-thirds with .16 per cent. The tints should be compared by holding up the test tubes against the light from the sky, and they should be changed from side to side during the comparison.

If a mouse is not available a sample of suspected air should be taken in a thoroughly clean bottle; open the bottle under the blood solution, allow a few centimeters of the air to bubble out and the blood solution to bubble in; shake continuously for ten minutes, then pour the solution from the bottle into a test tube and hold up to the light.

Decomposing organic substances containing sulphur give off sulphuretted hydrogen, which is best known to the miner as "stinkdamp." In small quantities it betrays its presence by its odor of rotten eggs, but it is in some respects a friend to the miner, as it often gives warning of the outbreak of a gob fire, and it is a further indication that the coal is heating spontaneously.

It is a valuable warning of the probable presence of carbonic acid or whitedamp, as both gases are produced by the heating of coal. Breathed in large quantities it deadens the sense of smell first, and rapidly produces unconsciousness. A very simple test is to expose a piece of white blotting paper moistened with a solution of lead acetate, which speedily becomes black.

It is frequently said that a man could breathe from 1 to 3 per cent. of sulphuretted hydrogen without injury, but this is ridiculous, for such quantities cause instant death. Very small quantities will cause irritation of the eyes and air passages, the eyes feeling as though dust was in them. Giddiness and vomiting is caused by .05 per cent. and .2 per cent. would kill a dog or cat in one minute.

LESS THAN A POUND OF COAL FOR A BRAKE HORSE POWER HOUR

A gas engine and producer, put on the market by the New York Engine Company, and recently tested, has made the ideal of the steam engineer an accomplished fact in spite of him. It was a single cylinder engine 15 by 21 inches running at 235 revolutions per minute and rated at 56 brake horse power, which was 85 per cent. of the maximum. The coal consumption went below one pound per horse power hour when the brake horse power was run up above the nominal rating, it being 0.90 lb. at 60 horse power and 0.88 lb. at 66 horse power. The cylinder compression went up to 190 lbs. and the explosion pressure as high as 500 lbs. The tests were made with a 50 kilowatt generator loaded with a water rheostat.

PRECAUTIONS REQUIRED FOR ELECTRIC PLANTS IN COAL MINES

By Sidney A. Simon.*

It is absolutely necessary to determine the value of the claims put forward by those favoring any particular design of protective device. On the one hand, such an investigation might lead to the necessity of adopting designs which in point of cost would prohibit the use of electricity entirely, while it might also show that costly designs for so-called protection are really sources of danger that defeat their own ends.

In underground working the atmosphere is usually warm and very often damp, or even wet. Due precaution should therefore be taken that the insulation of the winding and current-carrying parts of motors is of a character to resist the continued action of moist atmosphere.

The accumulation of coal dust on the windings should be avoided as much as possible, as it might form a conducting film or layer over the insulation to the frames. Periodical inspection and cleaning should be enforced as a preventive.

Motors should be placed in well-built chambers, properly lighted and ventilated with intake air, where there is less likelihood of water dripping from the roof, and where there is light for inspection and room to give access to all the working parts of the motor, and to which, by being as far as possible shut off from the main roadways, there is less liability for the penetration of coal dust.

If it is impossible to avoid dripping or spraying water by building the chamber with waterproof arches and walls, or by arranging a suitable roof over the motor to lead off the water and prevent it dripping onto the motor, it is necessary to have recourse to enclosing covers, which should be of the weather-proof ventilating pattern, designed so as to interfere as little as possible with the cooling of the motor. The covers, however, should be opened readily to admit of frequent examination of the windings with a view to preventing accumulation of coal dust.

The question arises whether the motor should be provided with any special protection as a precautionary measure to prevent danger in the case of the presence of firedamp not being noticed soon enough, and the motor not being stopped. It is generally believed that such measures are not necessary. Motors which require frequent stopping, starting or speed regulation, however, as, for the main and tail haulages, hoists, etc., would not be provided with short-circuiting and brush-raising devices, and there would be a likelihood of sparking occurring the whole time they were in service. Even for such cases, however, no hard-and-fast rule for enclosing can obtain.

Experiments were carried out for the purpose of determining the value of totally enclosing as a protection against explosion at the time of the Special Committee on the Use of Electricity in Mines. The tests of 1903 showed that practically all the protective devices fitted to motors proposed were either insecure and a positive danger in an explosive atmosphere, or ineffectual for mechanical or electrical reasons. Such, for example, were enclosing of complete motor with wire gauze or solid covers, enclosing of overhung slip rings in solid so-called gas-tight covers, or immersion of slip rings in oil. It was found on experimenting with motors that of all the various methods proposed as protective devices, the use of a labyrinth enclosure, an enclosure pierced with pipes, and the so-called flange enclosing are totally unreliable as protective devices, and must be rejected as unsafe. On the other hand, the complete enclosure in wire gauze and the "plate" protection, afford reliable methods of protection, and can safely be adopted when suitably applied. To these must be added oil immersion.

So far as the total enclosure is concerned, this method of protection is mainly available in cases where internal ventilation is not essential in order to carry off the heat generated in the apparatus. Apparatus or machinery in which heat is generated is, generally speaking, therefore not suitable to receive this method of protection. In oder to be effective, this complete enclosure has to be made very strong indeed, entailing considerable weight and initial cost. The protection by means of wire gauze permits of ventilation, and in this respect affords an advantage over a total enclosure. Wire gauze, however—which must

*From a paper before the Glasgow section, Inst. Elec. Eng.

be doubled to be safe—is very liable to mechanical injury, which would easily destroy its protective qualities. It must, therefore, be further protected by a mechanical safeguard. The plate protection affords ample ventilation, and at the same time ample mechanical protection, and should therefore be considered as the most suitable enclosure for all motors.

The protection by oil immersion is difficult of application to machinery which is in constant motion. It can with advantage be combined with plate or gauze protection.

In applying methods of enclosing, particular care should be exercised in the design of the machinery or apparatus to prevent any communication between large spaces through passages or apertures, where such communicating spaces might give rise to the development of exceedingly high internal pressure in case of an explosion occurring.

Where grouping in chambers is not possible, plate protection should be provided on the motors, the windings being enclosed in one enclosure and any part in which sparking is liable to take place in service should be enclosed in a separate enclosure, particular care being exercised to prevent any communicating passages between the two enclosed spaces, total enclosure being adopted only in the very smallest motors.

The switch gear should be of the enclosed type, either total or protected by "plate" protection or gauze, preferably with oil-break switches and cartridge fuses, and with no possibility of an explosion in one compartment being communicated to the gases in any other.

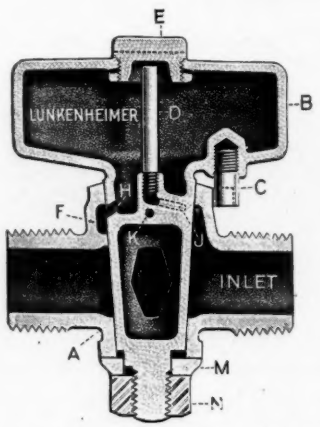
The largest electric transmission line in the world is that of the Niagara-Syracuse-Auburn line, which transmits 30,000 horse-power over a distance of 163 miles. The line in parts is designed to carry 60,000 horse-power.

In actual practice it has been found that 4 ozs. of calcium carbide at 4 cts. per pound will give nearly 10-candle power clear illumination, without smoke, for five hours. One-half pound, or 2 cts.' worth, will give the same illumination for 10 hours. Candles in many parts of the country, counting four candles to the 10-hour day, would cost 5 cts. per day.

AN AIR THROTTLE AND AIR OILER

The device here shown is a compact fitting which serves as a valve or cock for controlling the air supply for a rock drill or other air operated tool and also as a lubricant reservoir and feeder. It automatically admits a little oil—more or less according to the adjustment—every time the cock is closed and opened, thus making the lubrication both certain and practically continuous.

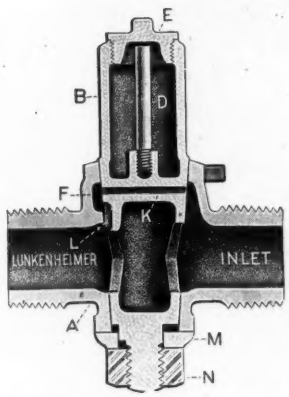
The handle serves as the reservoir for the oil and is filled by removing the central plug E. The valve is connected so that the pressure is taken at the end marked "inlet." The drill hole J communicates with tube D and registers with the inlet port when the cock is about half open, so that every time the valve is opened and closed the hole J passes the inlet port and allows the air pressure to enter the oil reservoir through tube D. This air pressure forces a charge of oil through passage H into the pocket F when the valve is entirely closed. When the valve is opened passage K registers



"OIL-AIR" COCK IN CLOSED POSITION.

with the inlet on one end and with pocket F on the other, allowing the air to blow through and force the oil out of the pocket and into the main air current and so be carried into the cylinder. This operation is of course repeated every time the machine is stopped and started. The reservoir can be refilled whenever the valve is closed.

The valve is made in four sizes: ½, ¾, 1 and 1 by ¾ inch, the smaller size being the outlet. The valve is strong and adapted to rough usage, the body being of malleable iron, the plug, filling cap and washer of bronze and the

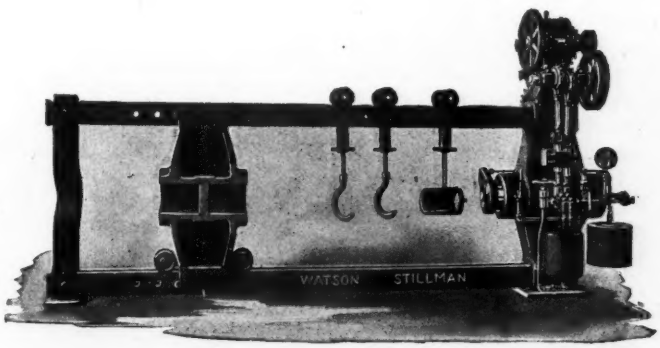


"OIL-AIR" COCK IN OPEN POSITION.

nut of steel, the latter with the body being made rustless by the sherardizing process. Made by the Lunenheimer Company, Cincinnati.

pumps and into the main cylinder, thus pushing the ram out very rapidly instead of waiting to have it slowly worked out by the pumps. These pumps are electrically driven and are in motion while the air advances the ram, so that the final pressure is applied at once when the air is shut off.

In the press design as here shown attention is called to another important improvement. To do away with a heavy base plate and to eliminate the tendency to spring sideways with heavy work the single bar above and below as formerly used has been discarded and a pair of bars 3 to 6 inches apart substituted for each. The ram and the movable abutment are central between these bars, the thrust always coming inside them. Other features facilitating rapid work are the trolleys for the suspension hooks and compression cap, and the traveling wheels for the movable abutment.



A HYDRO-PNEUMATIC WHEEL PRESS

The half tone shows a hydraulic wheel press built by the Watson-Stillman Company, 50 Church street, New York, which has been substantially improved by the addition of the pneumatic feature. As it may be assumed that wherever a press of this type is installed there is always a supply of compressed air, it is a simple matter to connect it by either an air hose or permanent piping. The air connection is through a separate three-way valve to the closed cylindrical reservoir at the right. When the ram is at the back end of its stroke as shown this reservoir is almost filled with water. The admission of air to the reservoir forces the water under pressure through the

A COMPRESSED AIR HAULAGE RECORD

For 32 years compressed air has served the general transportation system of the Plymouth Cordage Company, Plymouth, Mass., with its buildings extending 2,500 feet in length and 1,000 feet in width. In the selection of compressed air the determining consideration was safety from fire. The first locomotive was purchased in 1876 and it is, and has been in active service continuously through its 32 years' life, with a surprisingly small amount spent for maintenance. It is fair to say, however, that the work at the Plymouth Cordage works is undoubtedly light in comparison with what it would be in a mine or a metal working plant.

Also, that the method of using the air, as regards pressure and some other details, is open to criticism. These latter points, however, do not seriously impair the efficiency of the arrangement as a whole, and are the natural outcome of a many times outgrown and expanded system. The locomotives are charged at various points about the plant. The charging valves are located particularly with the idea of having the tank filled at the same time that the cars are being loaded or unloaded. Some of the runs are quite long, the longest being 2,400 feet, and the round trip, under favorable weather conditions, is made with one charge. On this run a net load of 8,500 pounds is carried, and the cost of air figures .04 of a cent per ton per 100 feet. Other runs figure .08 of a cent per ton per 100 feet. This cost is based on a cost of one-half cent per 100 cubic feet of free air, and includes all charges up to delivering the air into the mains at 200 pounds pressure; these figures are on the conservative side. This system, as a whole, taking lump figures, moves 1 ton, net load, 100 feet for approximately 1 cent. This includes the air used for all other purposes, fixed charges on all the rolling equipment as well as compressing apparatus, and all attendance.

NITRATES DIRECT FROM THE AIR

One of the most interesting events of the latest international congress of chemists was Prof. Bernthsen's demonstration of Prof. Otto Schönherr's new method of manufacturing air saltpetre, the manure of the future for food crops.

Prof. Bernthsen said that of all the things which agriculturists supply to the ground to stimulate the growth of crops, what are called nitrates are the most important. When nitrogen is omitted the yield of oats falls by 89 per cent. The rotation of crops supplies some of the necessary nitrogen to the soil, but much more is required, and this is best supplied by Chile saltpeter (sodium nitrate). The world's store of saltpeter, it has been estimated, at the present rate of consumption cannot last longer than from twenty-one to forty-two years. Sir William Crookes in 1899 said that the extraction of nitrogen from the air "is one of the greatest discoveries awaiting the ingenuity of chemists." It was this discovery which Prof. Bernthsen was describing.

Of the air we breathe more than three-fourths by weight is composed of nitrogen, but the problem is to make it chemically combine with oxygen to form nitric and nitrous oxides. This is accomplished by the agency of high temperatures, and the actual operation was demonstrated by Prof. Bernthsen with specially prepared apparatus.

This consisted, first, of a long narrow glass tube with a copper spiral running up it. At the sides smaller tubes carried running water to cool the upper connection of the spiral. From the top of the tube ran an iron tube with a stopcock to carry away the nitrogen oxides. A current is sent through the glass tube, and the compressed air which is sent in at the same time carries an arc flame up through the spiral to the other end of the tube. The flame makes the nitrogen and oxygen combine, and this is cooled down and carried away.

The current employed for the demonstration was at a pressure of 5,000 volts, and nearly 6 horse-power of electrical energy was used. The gas obtained is mixed with limestone, when calcium nitrate, or air saltpeter, is formed. A slightly different method gives calcium nitrite, which, being richer in nitrogen, may, said the professor, become the artificial manure of the future.

At zero Fahrenheit air is saturated with half a grain of moisture to the cubic foot, at 15 degrees with one grain, at 32 degrees with two grains, at 50 degrees with four grains, at 62 degrees with six grains, at 70 degrees with eight grains, at 85 degrees with twelve grains, at 100 degrees with twenty grains, with a gradual reduction of density of the air amounting to one-fifth.

It was discovered many years ago that nitrogen is absorbed directly from the air by certain nodules, which are found especially in leguminous plants. An English scientist, Jamieson, has discovered another method of direct fixation of atmospheric nitrogen. He finds that numerous plants are covered with hairs which absorb nitrogen, convert it into albumen, and then wither and become absorbed into the body of the plant. By examining with a microscope series of sections which had been treated with reagents which stain albumen, the migration of the absorbed nitrogen could be approximately traced. The phenomenon is of very general occurrence among plants.

COMPRESSED AIR MAGAZINE

EVERYTHING PNEUMATIC

Established 1896

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THE INNINGS OF PROGRESS

Every device of man seems to be predestined to be in its turn superseded, the better always coming later. No important invention, though ultimately doing extended and protracted work for the race, is fitted to do its best at first. Its possibilities do not all appear at once and its applications and adaptations must be slowly and laboriously adjusted. The work of perfecting goes on continually, but when anything is, as we think, most nearly perfect then is it most near its end for the world's employment.

The curious thing in the apparent law of progress is that the possibilities of the device which for the time is most successful and satisfactory must be so completely developed and appropriated, and it must be so fully and widely employed, before the new and different but still the more economical and otherwise more satisfactory agency asserts itself and secures the temporary lead.

We have been a full century developing and perfecting the steam engine, and at the beginning of the present century it might have been said to be then ready for a full century of steady work with little more in it of remaining possibilities to be developed; and yet it would seem to be actually losing its hold. "The high speed engine," says Professor Sweet, who had much to do in developing its efficiency, and establishing its success, but who could not make that success enduring, "must share the fate of everything else. It has served its purpose, has proved its right to existence, has been usful, and if it goes down with the Corliss engine it will die in good company."

The earlier reciprocating steam engines were successively improved out of existence. The high speed engine, which was the climax and the favorite, is being succeeded by the steam turbine, and in pursuit of even the latter the gas engine is beginning what promises to be a long and winning innings.

We may rather wonderingly ask, since the gas engine is not essentially a novelty, why it should not sooner have been permitted to show what it could do and then have been put to the doing of it. The answer is simple enough if we take a long view of the workings of the law of progress. One thing must have its chance at a time. The gas engine was not to be until the steam engine had exhausted itself in the way of improvement and had reached its culminating achievement.

In this view of it the days of compressed air are still far from numbered, and it may be nearer the beginning than the far end of its career of usefulness. These are the days when its abilities are developing and its employment is extending, and so long as this continues the end is not in sight. Permanent air compressing plants are multiplying and the details of compressed air employment are ramifying and extending. In certain fields compressed air is another rival of steam, and it is doing more satisfactorily and better what steam has been wont to do. It almost seems as if the big steam hammer should change its name and be known for what it now largely is in fact, as the air hammer. As is spoken of more extensively elsewhere in our present issue, machines and apparatus usually or traditionally steam driven when employed in extensive outdoor operations are more and more being driven from central air compressing plants. Electricity so far from superseding air finds additional employment through it. Electric driven air compressors are becoming numerous and the Electric Air drill is one of the phenomenal successes of the decade. Compressed air apparatus is still so far from perfect, compressed air practice, in some of its details, is still so crude, the possibilities of improvement are still so great that the end is not in sight.

ALPINE AND AMERICAN TUNNEL PRICES

Much has been written on the comparative value of the different methods in use in America and in Europe for driving tunnel headings. A heading is always understood to be a pilot for the main tunnel. Once driven it is then an easy matter to enlarge to the full section, so that the most difficult and expensive part of tunnel work is the driving of the heading, and the rate of progress of the whole is dependent upon it.

It is generally admitted—in fact it cannot be disputed because of the records of actual performance—that Alpine tunnels have been driven at a rate of progress nearly double that with which we are familiar in America, and where the conditions are similar. Driving in hard rock is quite a different proposition from driving in soft rock, or in material of varying hardness.

The latest of the Alpine tunnels, the Loetschberg, is being driven from two headings; that on the Northern end being through material more or less soft and classed as limestone, while on the South end, where American made machinery is in use, the rock is hard gneiss, and the progress through this material has been double that of American tunnels driven in the same kind of rock, the maximum record being about 600 ft. per month.

We understand that the contract price per cubic yard of material removed at Loetschberg is in the case of the North heading about $2.25 a yard, while in the South heading it is about $3.25, and that the heading dimensions are approximately 8½x8½ ft. This means that in the hard rock section the contract price per yard of heading advanced (place measurement) is $27.00, which compares very favorably with prices which we are accustomed to deal with here. For instance, the price per cubic yard at the Newhouse Tunnel in Idaho Springs, Colo., with a cross section of 12x12 ft., is said to be $2.95, which would make nearly $50 per lineal yard advanced.

At Ouray, Colo., the Chipeta Tunnel was driven at an expense of $4.15 per cubic yard or $22.35 per yard advanced. The material here was quartz and the dimensions of the tunnel considerably less than the Loetschberg. In 1908 a small heading was put through in the Newhouse properties in Colorado at an expense of about $6.50 per cubic yard.

The main point of interest is that in the South heading of the Loetschberg tunnel, where hard rock is encountered, American made machinery, using the European system with tunnel carriage, has made double the progress per month, and that the price per cubic yard is not higher, but is, in fact, lower than that which we are accustomed to meet in this country in tunnel driving under similar conditions and in tunnels of approximately the same dimensions.

FLAMES IN COMPRESSED AIR PIPES

The following letter we take from the July issue of the publication indicated, the editor appending a note asking for accounts of similar experiences:

Editor Mines and Minerals:

SIR:—Several days ago the puncher machine boss claimed that he saw flame coming out of a puncher machine, 1,500 feet from the shaft bottom. There are two Ingersoll-Rand

compressors on the surface which furnish air at from 60 to 80 pounds pressure. At the time the machine boss saw the flame there was an explosion in one of the compressors accompanied by a loud report. I went to the air receiver on the surface about 20 minutes after the explosion and found the receiver so hot that you could not touch it. The receiver has a pop-off valve on it. Would it be possible for the flame from the receiver where the explosion occurred to carry through the air lines to a point where there was an opening in the air line or to the exhaust of a puncher machine?

PHILIP STOUT.

Gates, Pa.

We may say that the occurrence of flames in the air receiver and air pipe is not a novelty, and the explanation would seem to be a simple one. It is quite possible for an accumulation of oil in the receiver, or in the pipes near the compressor, to be ignited and for the flame to be carried along through the pipes even to the exhaust of the puncher.

The writer hereof had an experience in this line on the Croton Aqueduct work more than a score of years ago. As an experiment, a large piece of asbestos saturated with kerosene was ignited and enclosed in the 4-inch air main. The flame extended throughout the main from the point where the asbestos was located to the rock drills working in the heading of the tunnel, something like half a mile away, and we were present in the heading when the flame was discharged at the exhaust of the drill. This of course lasted but a short time and the gases fouled the air, which of course the men had to breathe, so that it was necessary to extinguish the flame by shutting off the air supply and blowing out the pipes.

The remedy for the flowing of oil in the air receiver or pipes is, of course, to keep a clean compressor and discharge passages and connections, a clean receiver and pipe line and to use good oil and not too much of it. It is a common error in compressor plants to feed oil into the air cylinder about as fast as into the steam cylinder, which is a great mistake. Not one quarter as much oil should be fed into the air cylinder as into the steam cylinder, and it is a good thing to clean out the valves and passages by feeding soapsuds through the regular oil cups for, say, half a day each week and then resume the oil feeding.

When the flames occur, and at the points where the flame actually exists, the danger of explosion is presumably past, as that would occur if at all at the instant of ignition. The proportions of air and of volatilized oil to constitute an explosive mixture are limited in both directions, and continuous flame would seem to indicate an excess of oil beyond the explosion point. The production of flame without destructive explosion would seem to be an endorsement rather than a condemnation of the oil used, showing that it had no volatile constituent to be given off in sufficient quantity to form an explosive mixture with the air before the temperature of spontaneous ignition was reached. Whatever the oil used it remains imperative to keep the receiver and piping as free of it as possible.

NEW BOOKS

Mr. Lucius I. Wightman, B. S., E. E., has prepared for the American School of Correspondence, Chicago, two "Instruction Papers" on the subject of Compressed Air. These are in fact books, copiously illustrated, finely printed and neatly bound, comprising 162 pages 6¾ by 9¾ inches. The principles involved in the production, transmission and application of compressed air are concisely presented, compressors and appurtenances and the leading and typical air actuated apparatus are described in general and in detail, so that a wonderfully clear and complete presentation of the entire subject is achieved. Each "paper" is supplemented with a series of questions which, if the student can answer them all precisely and correctly, will attest his mastery of the subject. The books should be of service to a great number of those who, not wishing to enroll themselves formally as students, still wish to acquire practical information, especially when it can be got so easily as from these pages.

AIR PRESSURE AND WAGES

An agreement has been reached between the Compressed Air Worker's Union and the employers of New York and vicinity whereby the 1300 workers in this dangerous business, who formerly were paid in proportion to the depth to which the caissons were sunk, will be paid

instead according to the air pressures in which they are compelled to work.

They will receive $3.50 a day for six hours, at 22 pounds pressure; $3.75 a day for six hours at from 22 to 30 pounds pressure; $4 a day for four hours at from 30 to 35 pounds pressure; $4.25 a day for three hours at from 35 to 40 pounds pressure, and $4.50 a day for one hour and twenty minutes' work at from 40 to 45 pounds pressure.

BALDWIN LOCOMOTIVE WORKS

The following paragraphs constitute the official announcement of the recent incorporation of the Baldwin Locomotive Works:

By mutual agreement, the firm of Burnham, Williams & Co. has been dissolved and its entire property and interests in the locomotive business have been sold to the Baldwin Locomotive Works.

The Baldwin Locomotive Works, a corporation organized under the laws of the State of Pennsylvania, has this day purchased the entire property, business and good-will of the firm of Burnham, Williams & Co., and assumed all its assets and liabilities.

NOTES

The book departments of the McGraw Publishing Company and of the Hill Publishing Company were consolidated on July 1st, under the corporate name of the McGraw-Hill Book Company, with offices at 239 West 39th Street, New York City.

The El Paso branch office and warerooms of the Sullivan Machinery Company are now located at 506-8 San Francisco street, instead of at 206 St. Louis street as heretofore. Sullivan air compressors, diamond drills, rock drills and other mining machinery are carried in stock.

Mr. Ernest McCullough has resigned as chief engineer of the Northwestern Expanded Metal Co. to become an associate editor of *Engineering-Contracting*. Mr. McCullough is author of "Engineering Work in Towns and Cities," "Manual of Reinforced Concrete," "Business of Contracting," "Municipal Public Works," "Engineering Contractors' Pocketbook," etc. He has had a practical experience of 22 years and is generally recognized as au-authority on matters pertaining to municipal work.

Mr. A. Bradshaw Holmes, secretary and treasurer of the Independent Pneumatic Tool Company and the Aurora Machinery Company, Chicago, died on June 30th, thirty-one years old. Mr. Holmes was well known in the pneumatic tool business, having previously been connected for a number of years with the Standard Pneumatic Tool Company and the Rand Drill Company.

The work of cutting the Cape Cod canal was begun by the turning of the first sod on June 22d. This will be a sea level canal 12 miles long with a surface width of 250 to 300 feet, a bottom width of 160 feet, a depth at low water of 25 feet. No unusual difficulties or unusual expense will be involved in the work, while when completed it will be of great value and importance, not only for its local service but as forming an end link in a chain of interior waterways by means of which safe and protected navigation will be secured from Boston to Norfolk.

The rind of sugar cane contains a certain proportion of wax which has hitherto been lost with the refuse. By the new process this wax is now recovered from the filter refuse and turned to commercial uses, being very similar in its characteristics to beeswax or Carnauba wax, which can be used for precisely the same purposes. The wax, which resembles that now used very largely for making cylinders for so-called talking machines, is exceedingly hard and capable of taking a high polish. It is understood that many factories in Java will this year be using this process.

The change of air in a closed room has been investigated by Mr. Arthur D. Little, of Boston. The room, having a content of 615 cu. ft., was in the second story of an ordinary frame dwelling house with clapboarded exterior walls. The interior walls and ceilings were plastered and papered, the single window was made as tight as possible by means of putty and the interior door was fitted with weather strips. Notwithstanding these conditions, which one might assume would very materially limit the rate of ventilation, it was found that through perfectly

natural causes the air was changing at the rate of one and eight-tenth times per hour. This fact was shown by measurement of the rate of disappearance of carbonic acid.

A very curious application of the properties of calcium carbide has been made in Australia; namely, to the quick and easy determination of the quantity of water contained in wool before shearing. A little wool is clipped off, weighed, and mixed thoroughly with an excess of calcium carbide, in a suitable apparatus. The acetylene produced by the reaction of the carbide with the water in the wool is determined by measuring its volume at constant pressure or its pressure at constant volume, by means of a scale so graduated as to give directly the proportion of water in the wool.

A new safety lamp for mines has been invented. The lamp is placed within a large glass globe, which is airtight. Between the lamp and the globe pure air is enclosed, and when the lamp is lighted, the air is expanded by the heat. In case the lamp should be so injured as to expose the incandescent filament to the gases in the mine, the compressed air between the two globes is driven into the broken lamp before the air of the mine can enter. The influx of compressed air extinguishes the lamp before the explosive air of the mine is able to reach it. The lamp is fed by a single-cell storage battery.

Observations of the height of clouds made by directing a searchlight vertically upwards and determining the angular elevation of the illuminated patch of sky from a fixed base station were continued at the astronomical observatory at Vienna during the summer of 1908. Tables giving the results of observations for fifty evenings were recently published. The results show that media capable of reflecting the light were frequently found to exist at heights greater than 10 kiloms (6.21 miles). The column of light could be traced up to an altitude of 17.1 kiloms. on May 31st and 16 kiloms. on July 27th. The greatest cloud height (Ci.-Str.) was observed at 8 kiloms.

Pumping artesian wells by the air lift, instead of by a steam operated walking beam system, has effected a great reduction in the cost of fuel at Bradford, Pa., according to the last report of the water board. The city purchased and installed a 75-hp gas engine and air compressor. The cost of fuel per day pumping water by steam had been $7.20, but with the gasoline-driven air compressor, the cost per day for fuel was only $0.60. Other advantages claimed for the newer system were that it could be started up at a moment's notice and that no expense was incurred in looking after and repairing old rigs.

Experiments were made recently by Mr. E. A. Watson for the object of determining the manner in which the dielectric strength of air changes when it is compressed to pressures higher than atmospheric, with a view to its employment for the insulation of high-tension apparatus for which oil is not suitable. It was found that dielectric strength, expressed in kilovolts per centimeter $= 20 + 25.6P$, where P is the pressure in atmospheres absolute. This formula holds for values of P between 3 and 15, and it shows that the dielectric strength reaches values as high as those of solid or liquid dielectrics.

In a report from India it is stated that not far from the city of Chittagong natural gas issues from a crevice in the ground in considerable quantity. It has been burning so long that the oldest inhabitant can give no idea of when or how it was set on fire. The general belief among the natives is that the gas has been on fire for centuries. It is now suggested, and some steps have been taken to carry out the suggestion, that the fire be extinguished and the gas be brought under control, and piped for lighting, fuel and power purposes. It might be supposed that oil also would be found here as at Baku, in Russia.

The effect of air filters on the capacity of fan ventilating systems is indicated by the results of a series of tests recently made on such a plant with a cheesecloth bag filter using 9 in. bags, 10 ft. in length. With clean filter surfaces, 20,030 cu. ft. of air per minute was delivered through it at a velocity of 558 ft. per minute, while with the filter surfaces in a dirty condition the capacity of the system was reduced nearly one-half, but 10,430 cu. ft. be-

ing passed per minute at a velocity of 298 ft. With the filter entirely removed, the fan delivered 22,715 cu. ft. per minute at a velocity of 649 ft.

Outdoor mining of anthracite coal is to be started on an extensive scale at St. Clair, Pa., where the St. Clair Coal Co. has awarded to Contractor Thomas Nolan, of Reading, the extensive work of stripping off the surface earth from the mammoth vein, so that coal can be mined under the broad light of the sun. Millions of tons of coal can be secured in this way, although the largest steam shovels in the country will be at work on the preliminary excavating six or seven years before the coal can be secured. By this method all of the coal is of course removed, as far as the vein is worked. After the operations are sufficiently advanced the excavation also becomes its own dumping ground.

The field of mining engineering is the broadest field of engineering in the world. It presumes a knowledge of geology, crystallography, petrography, geography, trigonometry, surveying, of milling, cyanidization, amalgamation, chlorination, concentration, air and oil flotation, lead smelting, copper smelting, matte smelting and refining, of hyrdaulics, mechanics, thermo-dynamics, and electricity, of the laws of a hundred lands and the customs of a thousand mining districts, of transportation by land, rail, tram and sea; moreover, the engineer is supposed to be "wise" to all business tricks, schemes and devices of clever and deceitful sellers on the one hand, and of shrewd, unscrupulous buyers on the other.—*Mining and Scientific Press.*

A. Gaston Danville says that aviators make a mistake by practising soaring flight in a horizontal plane. This method makes use of air resistance to overcome weight and in this way excludes all development of progress. He adds that the proper course would be an undulating flight, which would first use air resistance to overcome weight and then use weight to overcome air resistance. In support of this view he cites the experiments of Capazza and Lilienthal. According to this view, in undulating flight gravity would furnish a motor destitude of weight, using no fuel, and of unlimited power, the only motor able to produce speed comparable to that of birds and to overcome the action of the strongest winds.

Candles, which are largely used throughout western mines, remove seven times and kerosene five times as much oxygen as acetylene. The products of combustion given off by candles are ten times and from kerosene nine times as much as that given off by acetylene. The actual amount of illumination given by candles and kerosene is lessened in a very large percentage by the smoke and mist which so rapidly accumulate, whereas all the light given by acetylene reaches the point to be illuminated without interference.

Air will cause corrosion in boilers. Cases of rapid corrosion have been proved to have been caused by the feed pumps sucking air from the feed hot-well. Small bubbles of air expelled from the water on boiling attach themselves to the heating surfaces. The oxygen in the air at once begins to act on the iron and steel, and forms iron rust, making a thin crust which, when washed away by the circulation, leaves beneath a small hole or pit, and pitting once started progresses rapidly. To prevent the air from entering the boiler the hot-well water should be pumped to a filter tank 8 ft. to 10 ft. above the feed-pump suction valves. Air then rises and is liberated from the surface of the water, and a head of water at the suction valves of the pump is assured.

A remarkable ascent has been recorded by one of the small balloons which for some time have been sent up from different places in order to investigate the conditions of the upper atmosphere. To the balloons are attached self-registering apparatus that give informa-as to the height attained, the temperature at that height, the hygrometric conditions that obtain, and the velocity of the wind. The balloons, which are made of india-rubber and filled with hydrogen, attain, as a rule, an altitude of from 10 to 15 kiloms., though heights of 25 kiloms. have been reached. The maximum record was obtained during an ascent from Uccle, a suburb of Brussels, to which the Royal Observatory of Belgium has recently been removed. The instruments recorded a height of 29 kiloms., or about 18

miles, some three times the height of the highest mountain on the earth's surface. The thermometer fell to 63.4 deg. below zero Centigrade, but this was slightly above the minimum, which had been passed at the moderate altitude of 15 kiloms.

A very simple test can be made to show the volatility of gasoline by moistening the hand with the liquid and noting the time it takes to evaporate. Common stove gasoline, known as 74 test, will take from 7 to 19 seconds to evaporate, leaving the surface of the hand perfectly dry. Lower grades will take much longer time. Should there be any greasy residue left on the hand the fuel is not fit for use in a gasoline engine.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

JUNE 1.

923,169. AIR-LIFT PUMP. OTTO E. HARRIS, Indianapolis, Ind.

1. An air lift pump comprising an upwardly directed air nozzle, a tube of greater diameter than the air nozzle arranged with its lower end open to a water supply and embracing the upwardly directed portion of the air nozzle, and having its upper end permeable for a distance below its upper extremity, and a second pipe of larger diameter than the first pipe with its lower end embracing the permeable upper end of the first pipe at a distance therefrom and open to the water supply.

923,237. PNEUMATIC-DESPATCH-TUBE APPARATUS. OAKES AMES, Milton, and ISAAC W. LITCHFIELD, Boston, Mass.

923,263. STRAIGHT LIFT PNEUMATIC. WILLIAM E. HASKELL, Brattleboro, Vt.

923,277. SPRAYING DEVICE. ARNOLD KLINGER, Chicago, Ill.

923,281. PNEUMATIC-DESPATCH-TUBE APPARATUS. ISAAC W. LITCHFIELD, Boston, Mass.

923,308. PNEUMATIC - DESPATCH - TUBE SYSTEM. CHARLES F. STODDARD, Boston, Mass.

923,368. VACUUM FLY-TRAP. IDA A. MYSER, Rifle, Colo.

923,437. AIR-COOLING APPARATUS. WILLIAM A. MERRALLS, San Francisco, Cal.

923,444. AIR-PURIFIER. HARRY A. ROBINSON, Chicago, Ill.

923,458. PNEUMATIC - DESPATCH APPARATUS. CHARLES F. STODDARD, Boston, Mass.

923,459. PNEUMATIC - DESPATCH - TUBE SYSTEM. CHARLES F. STODDARD, Boston, Mass.

923,550. DEVICE FOR THE UNIFORM SPRINKLING OF LIQUIDS. HANS MIKOREY, Schoneberg, near Berlin, Germany.

923,568. PRESSURE - REDUCING VALVE. FILIBERTO NICOLA, New York, N. Y.

923,587. APPARATUS FOR RAISING LIQUIDS. VITUS SCHWANINGER, Oggersheim, near Mannheim, Germany.

923,604. COMPRESSED-AIR REFRIGERATING APPARATUS. CHARLES TELLIER, Paris, France.

923,607. UNLOADING DEVICE (for Air Compressors). JAMES TRIBE, Milwaukee, Wis.

923,653. AIR OR WATER BLAST MAGNET. JOHN D. HILLIARD, JR., and CHARLES E. PARSONS, Glen Falls, N. Y.

923,698. WIND-POWER MACHINE. JONATHAN PERRY, Cambridge, Mass.

JUNE 8.

923,822. ATOMIZER. FRANK C. DORMENT, Detroit, Mich.

923,846. PROCESS OF EXTRACTING NITROGEN FROM AIR. OLIVER P. HURFORD, Chicago, Ill.

923,881. HYDROPNEUMATIC WHEEL. HENRI OUDINOT and CHARLES PUTOIS, Paris, France.

923,898. BOTTLE - BLOWING MACHINE. ADOLF SCHILLER, Schoneberg, near Berlin, Germany.

923,910. AIR-BRUSH. PETER THOMPSON, Toronto, Ontario, Canada.

923,936. AEROPLANE FLYING - MACHINE. AUGUST BERIOZZI, San Francisco, Cal.

923,984. SINKING SHAFTS AND THE LIKE. DANIEL E. MORAN, Mendham, N. J.

1. In the sinking of shafts, the method which consists in forming an open curb of molded and unincased concrete, and partially sinking the same, and then inclosing the lower part of the curb, and continuing the operation under compressed air.

924,024. VACUUM-PUMP. JOHN T. WILKIN, Connersville, Ind.

924,115. POWER AIR-PUMP FOR AUTOMOBILES. WILLARD J. SPENCER, Waterbury, Conn.

924,136. PROCESS FOR THE LIQUEFACTION OF GASES AND SEPARATION OF AIR INTO COMMERCIAL OXYGEN AND NITROGEN. GABRIEL A. BOBRICK, Los Angeles, Cal.

924,137. APPARATUS FOR LIQUEFACTION OF GASES. GABRIEL A. BOBRICK, Los Angeles, Cal.

924,280. AIR-COMPRESSOR AND DRIVING MEANS THEREFOR. MATTHEW C. SHARPNECK, Boston, Mass.

924,335. HYDRAULIC AIR AND OTHER GAS SUCTION APPARATUS. WILLIAM J. FRAME, Glasgow, Scotland.

924,350. ROCK-DRILL. HERMAN J. HIBSCHLE, Victor, Colo.

924,428. PROCESS OF SEPARATING OXYGEN FROM AIR. GEORGES M. A. CLAUDE, Paris, France.

924,495. AIR-SHIP. JAMES M. PARK, Pittsburg, Pa.

924,501. SPRAYING APPARATUS. ANTENOR SALA, Mexico, Mexico.

924,531. PNEUMATIC HAMMER. HERBERT A. BROCKWAY, Denver, Colo.

924,617. AIR AND VACUUM CONTROLLING DEVICE. HOSEA K. KRIEBEL and IRWIN Z. KRIEBEL, Philadelphia, Pa.

JUNE 15.

924,742. AUTOMATIC AIR-BRAKE APPLIANCE. JAMES A. COUCH and LEE F. COUCH, Nashville, Ark.

924,812. PNEUMATIC TIRE. DANIEL MCARTHUR, Jersey City, N. J.

924,813. FLYING-MACHINE. WALLACE A. MCCURD, North Finchley, England.

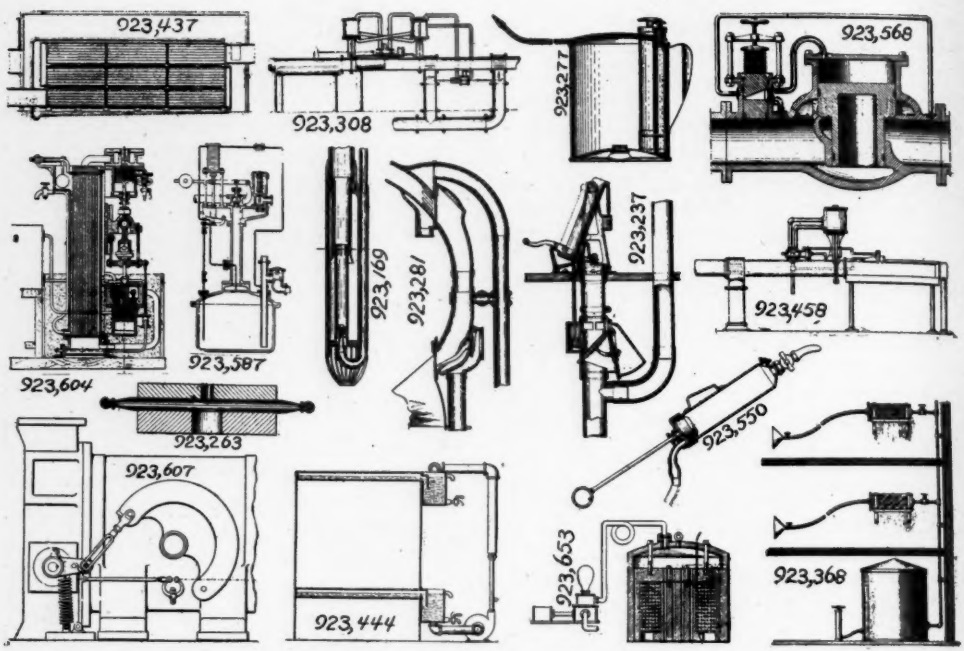
924,858. CASTING APPARATUS. ELBERT B. VAN WAGNER, Syracuse, N. Y.

924,909. WINDMILL-MOTOR. VALCOURE J. LA BAUVE, Houston, Tex.

924,980. SULFUR-BURNER. PAUL H. GRIMM, Glen Cove, N. Y.

1. A gas generating apparatus comprising a normally closed furnace, *an air pressure supply* thereto, a gas delivery therefrom, a normally closed fuel reservoir extending within and heated by the furnace and arranged to feed liquefied fuel to the furnace without exposure of the interior to the outside atmosphere, and means for supplying air pressure to the fuel reservoir.

924,942. COMPRESSOR OR EXHAUSTER FOR AIR OR OTHER FLUIDS. CHARLES H. SCOTT, Gloucester, England.



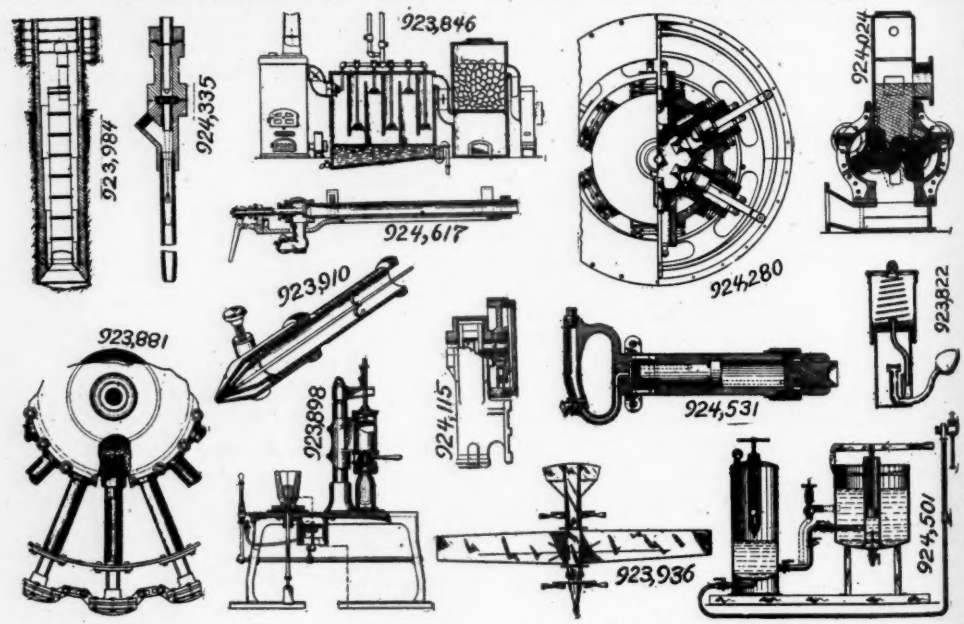
PNEUMATIC PATENTS, JUNE 1.

924,997. MILKING-MACHINE. DANIEL KLEIN, Spokane, Wash.

2. In a milking machine, a milk container, a cover therefor, a pulsator mechanism mounted on said cover, and a *pneumatic engine* adapted to be seated on said cover and operatively connected to the pulsator without fastening devices whereby the engine is readily removable from the cover and connection to the pulsator.

925,012. LIQUID-IMPELLING APPARATUS. WALTER B. MOORE, Walla Walla, Wash.

1. An apparatus of the character described comprising discharge pipe formed with an air inlet, means communicating with said pipe at one



PNEUMATIC PATENTS, JUNE 8.

side of the air inlet thereof or supplying the same with a liquid, means for discharging *air under pressure* into said pipe through the air inlet thereof, and a valve in said pipe normally preventing ingress of air, said valve being formed to permit of the liquid passing through the same while preventing ingress of the air, for the purpose specified.

925,203. AIR COMPRESSOR OR BLOWER. GEORGE W. LEIMAN and WILLIAM H. LEIMAN, Newark, N. J.

925,211. PRESSURE - RETAINING VALVE. BLYTHE J. MINNIER, Watertown, N. Y.

925,219. DEVICE FOR RAISING AND CONVEYING BEER FROM STORAGE VESSELS BY THE DIRECT INFLUENCE OF AIR-PRESSURE OF VARIABLE STRENGTH. JOHN H. W. ORTMANN and CARL W. C. HERBST, Hamburg, Germany.

925,274. SYSTEM OF MINE VENTILATION. DOMENICO BELLONI, Edri, Pa.

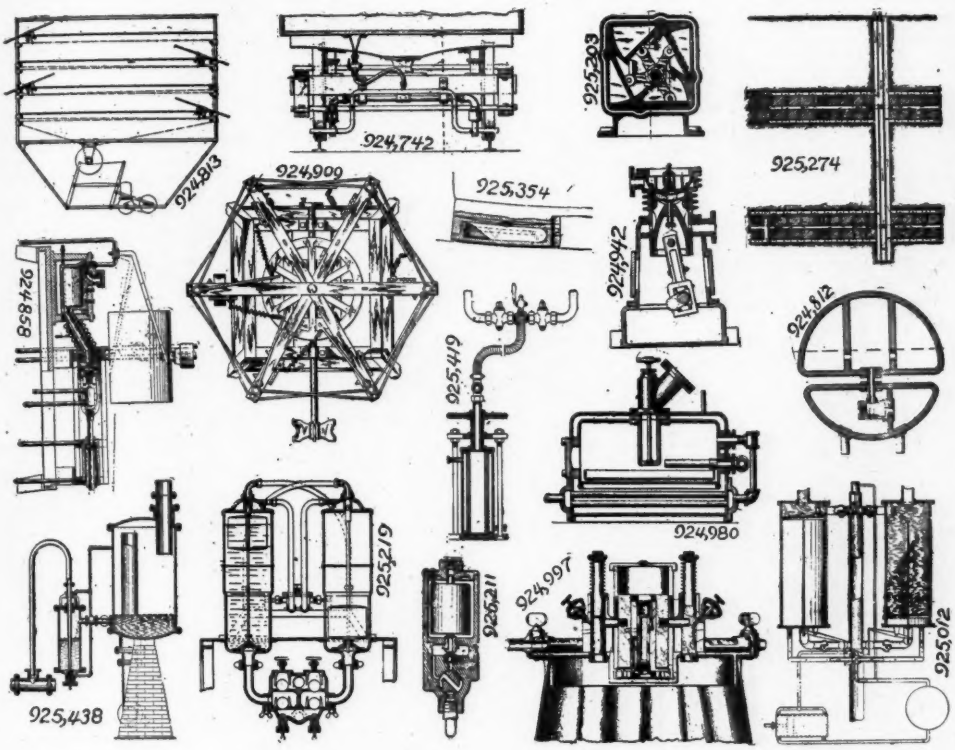
925,354. PNEUMATIC HEEL FOR BOOTS AND SHOES. JOHN V. LAMBERT, Chicago, Ill.

925,419. PROCESS OF INCREASING THE DENSITY OF FUSIBLE EXPLOSIVE NITRO SUBSTANCES. CHRISTIAN E. BICHEL, Hamburg, Germany.

925,438. AUTOMATIC DRAIN FOR COMPRESSORS. WILLIAM D. MOUNT, Saltville, Va.

JUNE 22.

925,491. MACHINE FOR SEVERING STAY-BOLTS. GROVER S. LOWE, Moline, Ill.



PNEUMATIC PATENTS, JUNE 15.

925,494. AIR-SHIP. PHILIP H. MCCONNELL, Syracuse, N. Y.

925,528. PNEUMATIC BRAKE FOR MOTOR-VEHICLES. ERNEST E. SWEET, Detroit, Mich.

925,566. AUTOMATIC AIR-BRAKE APPARATUS. JAMES O. DODGE, Los Angeles, Cal.

925,591. SAND-BLAST APPARATUS. JOHN C. PANGBORN and THOMAS HALL, Brooklyn, N. Y.

925,627. APPARATUS FOR PRODUCING UNIFORM FLUID-PRESSURE FOR ENGINES. ELMER ENGEBRETSON, Devils Lake, N. D.

925,646. PNEUMATIC DEVICE FOR COLLECTING AND REMOVING DUST. ALBERT E. MOORHEAD, Oakland, Cal.

925,765. ROCK-DRILL. SEYMOUR FERGUSON, Ocotolan, Oaxaca, Mexico.

925,859. AUTOMATIC AIR-TRAP FOR PUMPS. CHARLES S. AXFORD, Plainview, Nebr.

926,068. FLUID-PRESSURE BRAKE. WILLIAM P. A. MACFARLANE, Chicago, Ill.

926,075. CAPSULE FOR HOLDING COMPRESSED OR LIQUEFIED GAS. HARRY V. R. READ, London, and ROBERT H. CAMPBELL, Edmonton, England.

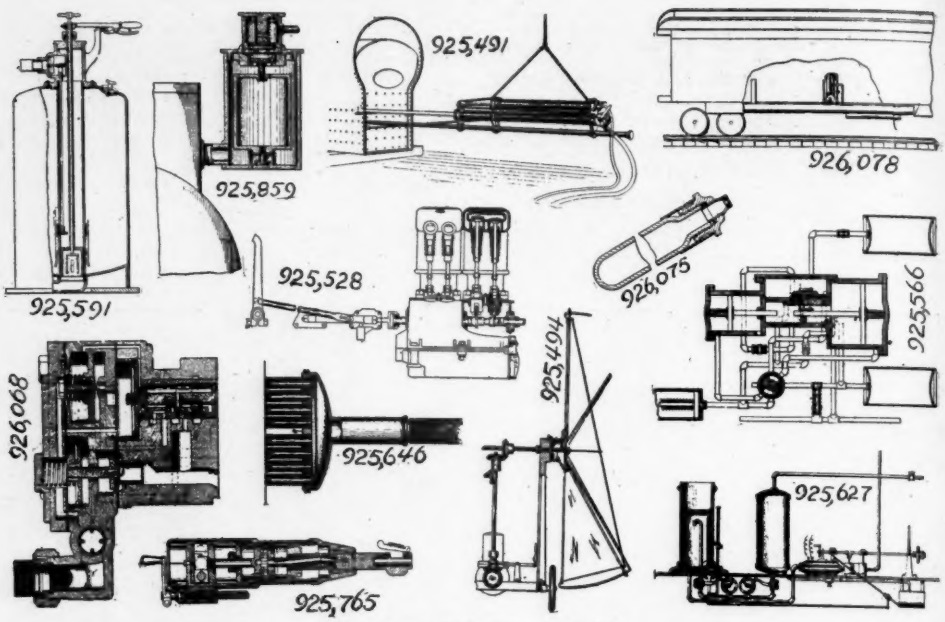
926,078. PNEUMATIC MAIL-HANDLING APPARATUS. THOMAS M. RIGGLE and WILLIAM M. BAKER, Tucson, Ariz.

JUNE 29.

926,124. AIR-COMPRESSOR. JAY B. LAMPMAN and AUGUST KITTELBERGER, New York, N. Y.

926,159. FLYING-MACHINE. JOHN H. WILSON, Middlesex township, Cumberland county, Pa.

926,217. FRESH-AIR INTAKE DEVICE FOR HEATING SYSTEMS. CHARLES H. SMITH and MICHAEL F. WEIDENBACH, Minneapolis, Minn.



PNEUMATIC PATENTS, JUNE 22.

926,260. PNEUMATIC ENGINE. DANIEL KLEIN, Spokane, Wash.

926,315. PNEUMATIC DEVICE. FRITZ BECK, Dumont, N. J.

926,413. PROCESS FOR OXIDIZING ATMOSPHERIC NITROGEN BY ELECTRICITY. DEMETRIO HELBIG, Rome, Italy.

1. A process for oxidizing atmospheric nitrogen by electricity in which compressed air is projected by two opposite nozzles arranged in line, against an arc produced between suitable electrodes, whereby two sheaves of flame are produced which spread out along the electrodes in a plane normal to the direction of the nozzles.

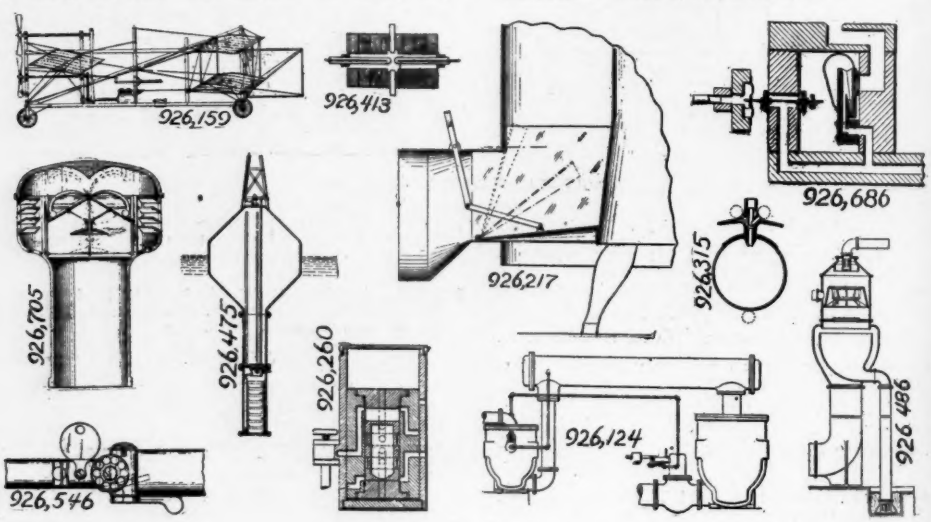
926,475. ACETYLENE-GAS BUOY. ROBERT M. DIXON, East Orange, N. J.

926,486. BAROMETRIC CONDENSER. ERNST G. HELANDER, Pittsburg, Pa.

926,546. MAGAZINE AIR-GUN. JOSEPH H. Cox, Aston, juxta Birmingham, England.

926,686. PNEUMATIC FOR WIND INSTRUMENTS. WILLIAM B. TUNSTALL, Melrose, Mass.

926,705. FRESH-AIR INLET. JACOB LEVY and EDWARD L. YOUNG, New York, N. Y.



PNEUMATIC PATENTS, JUNE 29.